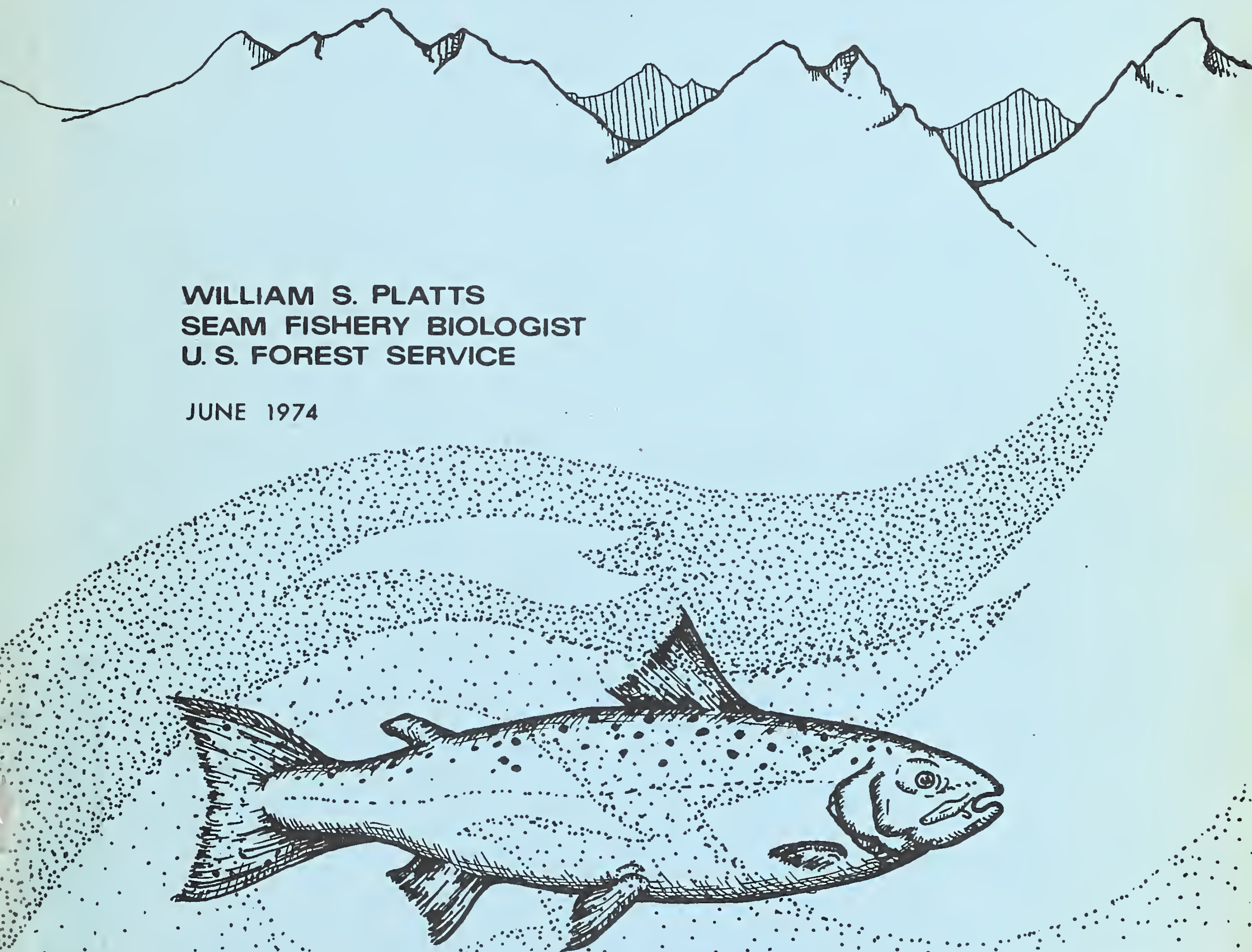
GEOMORPHIC AND AQUATIC CONDITIONS INFLUENCING SALMONIDS AND STREAM CLASSIFICATION

WITH APPLICATION TO ECOSYSTEM CLASSIFICATION



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JUNE 1974

SURFACE ENVIRONMENT & MINING
SEAM
U.S.D.A. PROGRAM

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June 1974

Library of Congress Cataloging in Publication Data

Platts, William S 1928-
Geomorphic and aquatic conditions influencing salmonids and stream classification.

Bibliography: p.
Supt. of Docs. no.: A13.2:Sa3/3
1. Salmonidae. 2. Rivers--Classification. 3. Limnology. I. Surface Environment & Mining Program. II. Title.
QL638.S2P55 597'.55 74-18461

*Surface Environment and Mining

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ABSTRACT

GEOMORPHIC AND AQUATIC CONDITIONS INFLUENCING SALMONIDS AND STREAM CLASSIFICATION

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Investigations were conducted from July 1970 through September 1972 of (1) the physical structure of aquatic environments in granitic, mountainous lands in Idaho, (2) the relationship between physical stream structure and fish populations, (3) the influence of geomorphic process of aquatic ecosystems, (4) the relation of order within landforms in relation to uniformity in aquatic environments, and (5) the potential for classifying aquatic environments from land classification systems. A 397 square mile area in the upper south fork of the Salmon River watershed was stratified into four geologic process groups and 12 geomorphic types. Within that area, 38 streams were studied by analyzing 2,482 transects for physical aquatic and streambank environments, while 291 areas were investigated as to fish populations.

The streams had distinguishing structural features that had resulted from the influences of geomorphic processes. In other words, streams that drained similar lands had been formed by similar processes. Such streams will therefore be relatively uniform in structure. The results of the two-year study allow classification

of aquatic environments within the granitic areas of the Idaho Batholith to the geologic process group level. Some specific environments can now be classified to the geomorphic type level.

Some areas of each stream studied had been dominated by one type of external variable such as glaciation. Multivariate control from geomorphic processes, however, exercised the most influence on general stream conditions. Spatial differences in dissolved and suspended substances in the streams appeared to depend on the degree of decomposition of bedrock and possibly on the elevation of the channel. Time, as related to streamflow movement through the drainage, had little influence.

In turn, certain aquatic structural characteristics controlled the density of fish populations and the composition of fish species. Stream depth, width, and the elevation of the stream channel were the most important such characteristics, with salmonids apparently adapted to almost all streams in these high elevation granitic lands. Variations in water chemistry did not seem correlated with the density of fish populations.

The fish population total density decreased or increased in a uniform manner as certain variables in the aquatic structure changed. Some individual fish species, however, responded in an opposite manner and certain species showed no correlation. The variables that described the structure of the study streams often proved to be directly related. If one changing variable were identified, most other structural variables responded in a predictable manner.

INTRODUCTION

Multidisciplinary teams have attempted to develop ecosystem classification as in "ECOCLASS." ECOCLASS is an unpublished attempt by the U.S. Forest Service to develop a way to classify ecosystems in the Pacific Northwest. This system was to be a prototype for a national classification. A major weakness in the ECOCLASS system has been having to work the aquatic phase of classification in with the terrestrial phase at the same levels of generalization.

The work reported here provides a solution to current difficulties. It is based on the idea that once ecosystems can be classified, they become identified units that can be meshed into land management programs (Figure 1). Aquatic resources merely need to be described and classified so they can be processed as workable units in land and water management. This is especially important in SEAM (Surface Environment and Mining) programs, as mining and milling constitute an especially difficult land use to fit into proper comprehensive land use planning.

This study provides information from mountainous aquatic environments that can be used to examine further the relationship of order and control in specific geologic and geomorphic settings. In my work, I quantitatively analyzed the relationship of geomorphic order to the existing condition of stream environments. Effects of stream condition on fish populations were also described so that the effects of geomorphic process on fish populations could be evaluated.

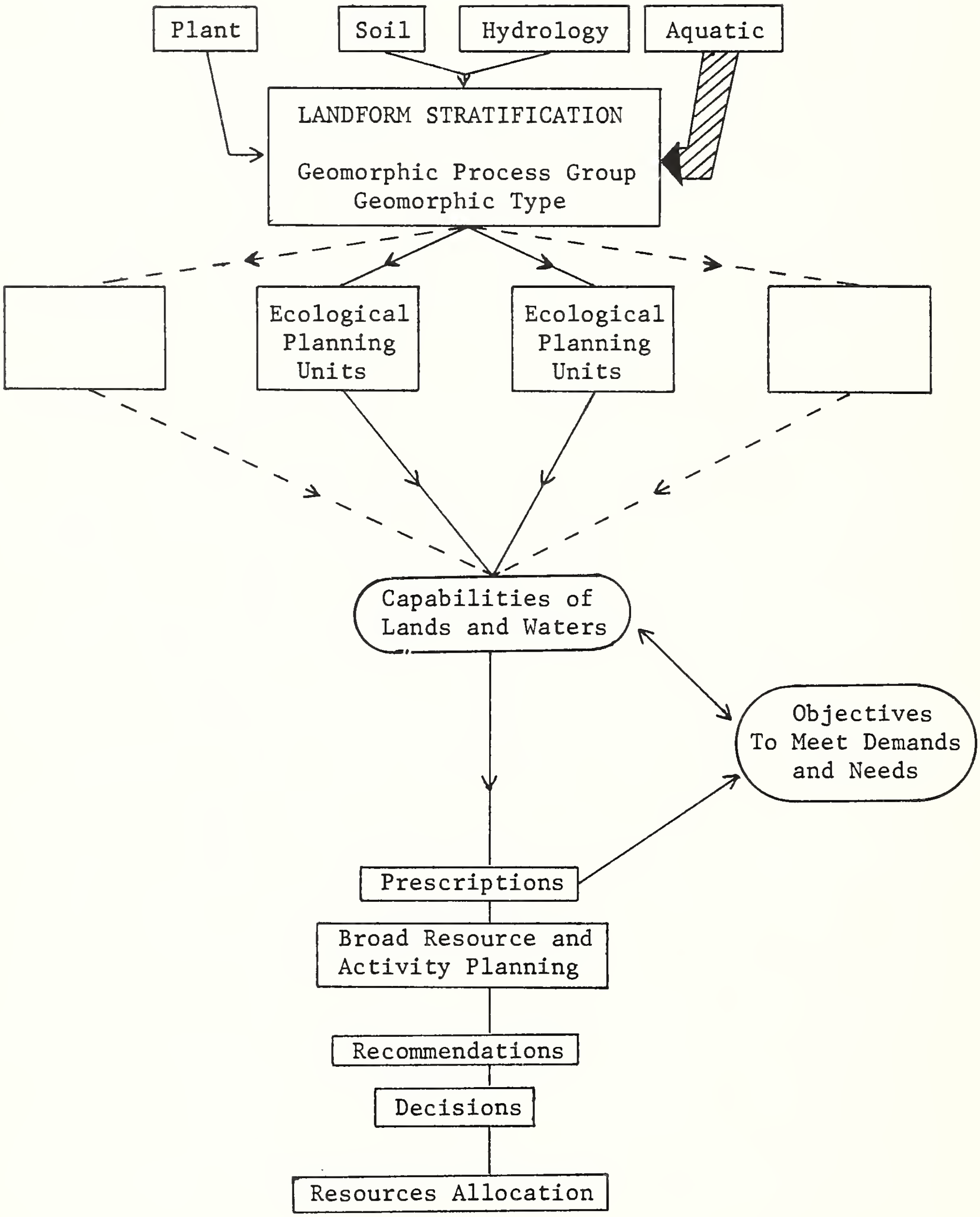

Figure 1. Flow chart of environmental management with phase of this study represented by shaded line linkage.

Geomorphic Process

Each geomorphic process develops its own characteristic assemblage of landforms as it shapes the landscape and its streams. Ninety-five percent of all landforms are sculptured by streams (Strahler 1974); landform and stream development inevitably occur together. Thus, the distinguishing features of streams should be dependent on the geologic and geomorphic process responsible for their development. Brush (1961) presented evidence that order is exhibited by the hydraulic environment of stream channels, but few data have been available for use in determining how this order varies in relation to the geologic setting.

Because running water is constantly changing the landscape, valleys are geologically young and it is generally accepted that little of the earth's topography is older than Pleistocene. Ashley (1931) made a strong case for the youthfulness of the world's topography and stressed that nearly all landform details have evolved since the emergence of man. In contrast, members of the Salmonidae family have been present since the Miocene, 28 million years B.P. (before present) (Berg, 1947). Consequently, salmonids have adapted their life cycle to erosion processes that continually change the landscape and create and maintain stream habitat.

Watershed-Stream Relationship

Streams are controlled by the watershed they help build, and each one reflects the geology, geomorphology, biology, climate, and

hydrology of its drainage basin. The watershed exercises its control over the streams by dictating or influencing physical and chemical conditions, which in turn help determine the character of the aquatic environment. Watershed and stream variables can be described, measured, and quantified. These variables thus allow identification and description of both the stream and its surroundings.

Describing and quantifying a stream condition and comparing it with the surrounding and influencing geologic process group or geomorphic type provides a way to evaluate the degree to which geomorphic controls affect or control the stream environment. With an understanding of the stream and its surroundings, we have the possibility of describing and classifying types of habitat in a stream from known geomorphic processes. Land classification maps, already completed by other disciplines, are then useful in classifying and better understanding fluvial aquatic environments. By combining the various classifications we can ultimately classify total ecosystems.

Classification

In the first part of this report, I describe specific aquatic environments in Idaho and compare them with other aquatic environments and their surroundings. Then these aquatic habitats are classified or described based on their inherent variables and variables from their influencing geologic process groups and geomorphic types.[1] The study area along the south fork of the Salmon River is young as measured by surface changes and has been subject to well-defined geomorphic processes. This provides circumstances

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[1] Geomorphic types are referred to in recent literature (Wertz and Arnold 1972) as landtypes and geologic process groups as landtype associations.

conducive to determining if fluvial aquatic environments can be classified or at least better understood on the basis of their surrounding land classification systems. The bedrock within the study area is almost entirely granitic, which minimizes the bias of mixed parent (bedrock) materials.

The study area was recently landtyped by soil scientists (Anonymous 1969) and is one of the first land areas to be stratified using mainly geomorphic processes (Figure 2). The aquatic environments thus can readily be compared with the different geologic process groups and geomorphic types in which they lie.

History

The aquatic environments of the south fork of the Salmon River and some of its tributaries have deteriorated in quality during the past several years because of increased sediment loads due mainly to logging and road construction (Figures 3 and 4). By 1965, 15 percent of the lands within the study area had been included in logging sale boundaries, and had yielded 325 million board feet of timber. Seventy-eight percent of the logging and 69 percent of the road construction were on fluvial lands, which are the least stable of all the lands in the drainage (Arnold and Lundeen 1968). Erosion rates were accelerated tremendously on disturbed areas, particularly on logging roads (Megahan and Kidd 1972), causing increased amounts of sediment to alter stream structure (Figures 5 and 6). Most of stream degradation occurred between 1962 and 1965; prior to 1952 the streams were in good condition (Platts 1968, 1970 and 1972). Following the elimination of logging and road construction in 1965, the streams have steadily improved.

Steelhead trout[2], chinook salmon, and resident game fish populations have steadily declined in the area since 1957 and there have been closures on the anadromous fishery. The decline of summer chinook salmon numbers and the deterioration of the salmon's upstream environment within the study area caused concern at local and national levels. The concerned public and the resource managing agencies, provided the money needed to initiate aquatic-fishery studies to identify the initial causes of the environmental degradation and to determine solutions. The initial studies showed how little is known about aquatic environments in mountainous lands.

Problem

If aquatic environments are to be managed in conjunction with our present deficiency of money, manpower, and data, some practicable way must be devised to understand, inventory, and classify the abiotic and biotic aspects of these aquatic environments. Comparisons of aquatic environment information with soil, hydrological, and geomorphic information can provide resource managers with the information they need in the form of a description and classification system.

Resource allocation that is compatible with conservation and maintenance of desirable stream environments can then be identified after the complete ecosystem is classified.

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2 Refer to Appendix A, Table 5 for scientific names of fishes as listed in the American Fisheries Society list of common and scientific names of fishes - 1970.

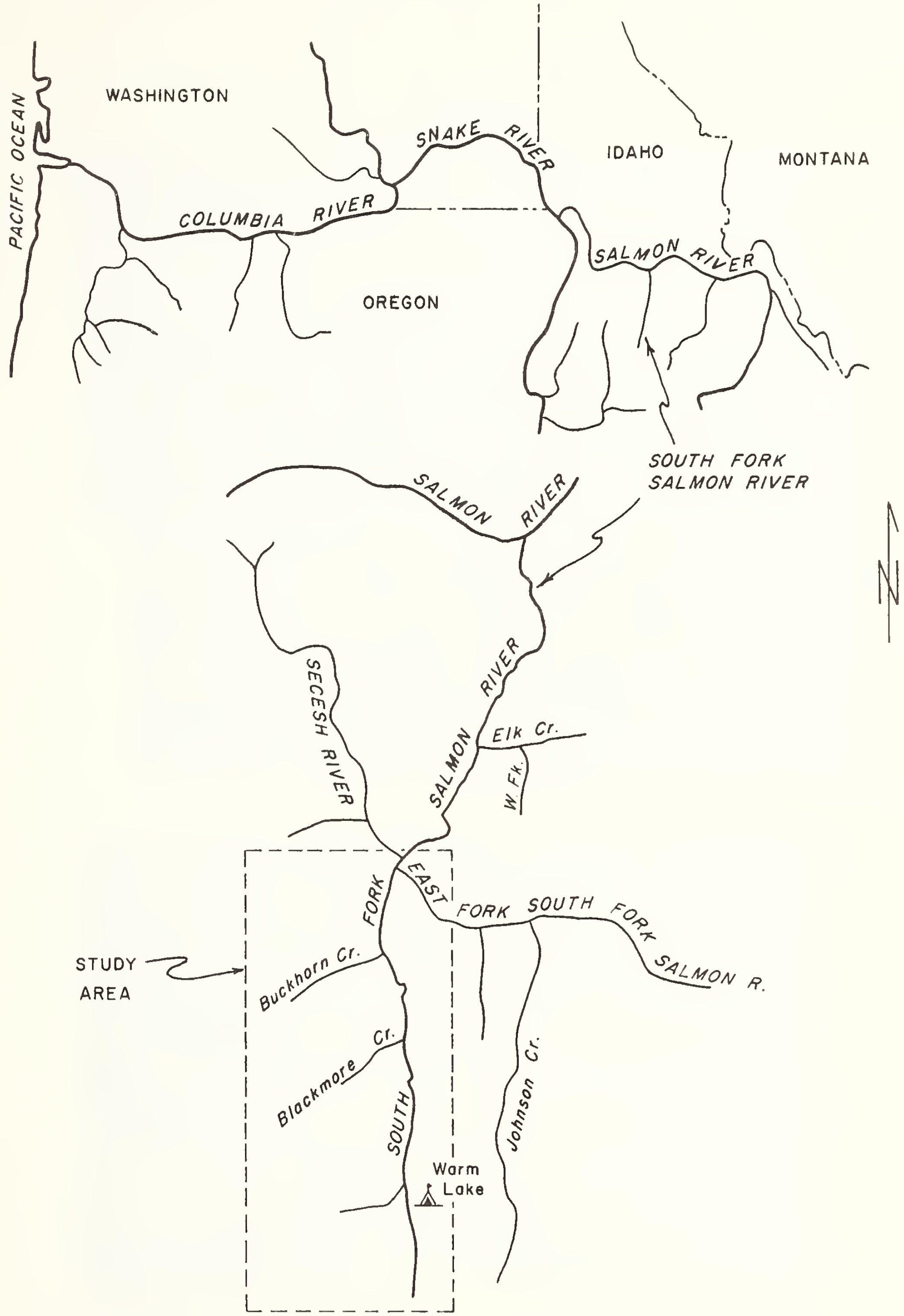

Figure 2. A portion of the Columbia River drainage with the location and further expansion of the South Fork Salmon River drainage and study area boundary.

Figure 3. A small drainage in the fluvial geologic process group within the strongly dissected mountain slope geomorphic type (120), disturbed first by fire, then by salvage logging, and finally by ineffective land rehabilitation methods (contour trenching). This area then "blew-out" putting large quantities of fine sediments directly into the South Fork Salmon River immediately upstream from its largest salmon spawning area.

Figure 4. Logged areas in the fluvial geologic process group located mainly in the dissected mountain slope geomorphic type (120). Logging and construction of roads on these lands were responsible for the main deterioration of the tributary and river environments because of increased sediment accruement.

Figure 5. Stream blowout resulting from logging roads in the fluvial geologic process group. Most of these mass failures of soil move sediment directly into the streams.

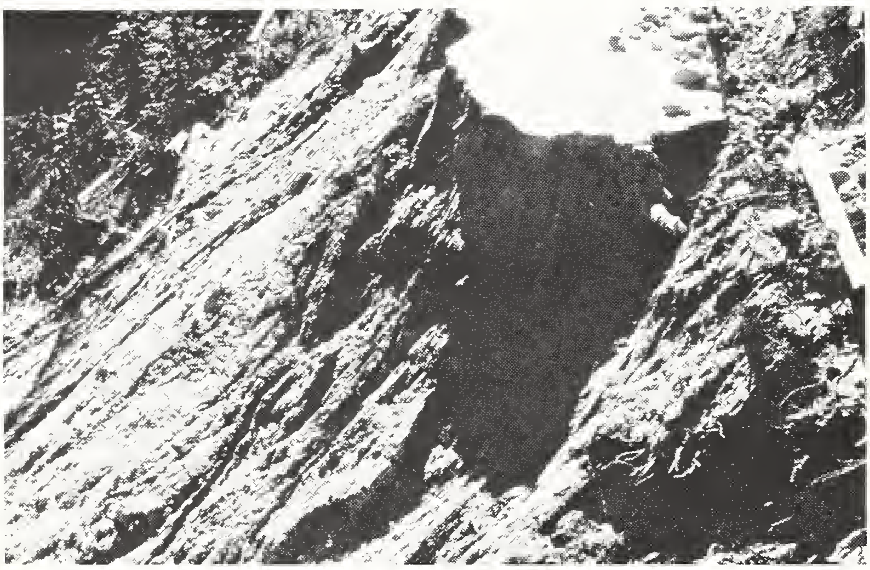

Figure 6. Mass failure of a road system occurring within the fluvial geologic process group. The failure was caused by rain on snow, which produced excess water flows (surface and subsurface) and caused road fill saturation.

OBJECTIVES

By quantifying aquatic physical conditions, I hoped to identify a relationship with standing fish crops and fish species composition that would permit comparisons with geomorphic conditions. In the study, I tested the hypothesis that landform control of the environment of streams (assuming similar lithology and similar landforms) would be uniform; therefore, specified landforms will always provide comparable aquatic physical, biological, and chemical conditions.

The specific study objectives were:

1. To determine if land classifications by geomorphic characteristics could be utilized to help describe or classify contained aquatic environments, thus providing the input needed for total ecosystem classification.

2. To evaluate the influence of geomorphic-physical conditions within a total watershed on its aquatic environments and the fisheries.

3. To determine how physical conditions within, and closely surrounding, aquatic systems affect fish populations.

4. To evaluate an aquatic environment inventory procedure as a predictor of fishery conditions.

5. To determine if aquatic environmental differences exist between disturbed (artificial conditions) and undisturbed (natural conditions) areas.

AQUATIC LITERATURE REVIEW

No published work was found that compared or classified aquatic environments by utilizing geomorphic processes or land classifications. Considerable research has been completed on the physical, chemical, and biotic phases of watersheds and their aquatic environments, but very little has been done to determine their relationships to each other.

Hydrological Studies

Numerous researchers have made detailed investigations on geologic and morphologic features of drainages. Physical characteristics of drainage basins have been studied by Strahler (1951, 1952, 1956, 1964), Miller (1958), Schumm (1960 and 1963), Schumm and Khan (1972), and Hack (1957). With the exception of Hack's study, the primary aims of the investigations were to present basic data and hypotheses relating such things as longitudinal profiles and valley slopes to other features of the basin in question and to its geology. Hack (1957) attempted to show that geology affects the hydraulic regimen, but the emphasis of his work was not on characteristics of the stream. Although many qualitative observations suggest that certain relations between geologic and hydraulic characters exist, quantitative data are insufficient to establish the nature of these relations.

Leopold and Maddock (1953), in quantitative studies, showed a correlation and interadjustment between parts of the landscape.

They demonstrated that stream discharge, sediment transport load, gradient, width, and depth are clearly interrelated. Findings by Shulits (1941) and Leopold and Wolman (1957) demonstrated that particle size determines longitudinal profile. Leopold and Miller (1954), Morisawa (1962), and Lubowe (1964), compared interaquatic structural variables with the surroundings and stated that stream gradient, stream width, length of stream, area of stream drainage, water discharge, shape of drainage basin, and relief have consistent relationships among themselves and with stream order within the same drainage complex. Hansen (1971) and Platts (1968) demonstrated that the substrate of river channels bore out definite, inverse relationships between boulders and fine sediments. Hely and Olmstead (1963), and Flint (1963), verified a close relationship between slope morphology and stream parameters. This was indicated in most streams studied by grading for removal of a load of supplied sediment from the watershed. These authors demonstrated that stream, slope of watershed, and pattern of drainage adapted to the structural lithology.

Einstein (1950) stated that if a stream is flowing in an alluvial valley over a bed composed mainly of unconsolidated sand or gravel, the stream and its channel will probably be essentially in equilibrium. Platts (1972) found that the composition of substrate material in a stream located in a disturbed watershed changed over time. Von Vertalanffy (1950) expressed the idea that systems in their responses to the surroundings may be dominated by one type of external variable. The trend, however, has

been toward recognition of multivariate control in geomorphic systems (Weber 1968). In areas having established streams. Weber (1968) felt that a rejuvenation of accelerated erosional activities would be transmitted rapidly to higher stream orders.

Interrelationships between various aquatic structural components have been investigated. Brush (1961) concluded that changes in size of particles in streambeds are erratic and do now show consistent relation to length of the channel, but he found a good correlation between size of particle and the slope. According to Bagnold (1956), many authors have recorded that the substrate of any channel normally, but not always, decreases in size from headwaters to mouth of the stream. Platts (1968) found that particle sizes in the channel of the south fork Salmon River in the lower 50 miles were larger than in the middle river section. Einstein (1950) reported that channels carrying uniform sand or silt appear to have less tendency to form pools. Platts (1968) visually observed and determined quantitatively in the south fork Salmon River that periods during which the water was carrying accelerated amounts of fine sediment, pools were covered up.

Biological Studies

Effects of various physical components of stream environments on their carrying capacities for trout have been reported by several investigators. Some of these studies involved evaluations of trout habitat improvement (Shetter, Clark, and Hazzard, 1946, Saunders and Smith 1955, and Hunt 1971). Other studies involved deleterious human alterations of trout habitat (Boussu 1954, Wickett 1958, Cooper 1959, Whitney and Bailey 1959, Elser 1968, Fredricksen 1970a,

Gunderson 1968, Hall and Lantz 1969, Hansen 1971, Kopperdahl and Burns 1970, Phillips and Campbell 1962, and Saunders 1965).

Changes in aquatic structure have been demonstrated to affect aquatic organisms directly. Cummins' (1966) extensive literature review found that no single factor has greater biological significance in the stream than the physical nature of the channel substrate. Excessive amounts of fine sediment within and on the streambed decrease productivity by smothering or crowding out the living organisms (Tebo 1955, Cordone and Kelly 1961, Cooper 1959, Phillips and Campbell 1962, Peters 1962, Koski 1966, Vaux 1962, and Vasil'ev 1964). Fine sediment particles deposited in the streambed cause salmonid redds to be less permeable to water. This results in higher mortality during the egg to fry development (McNeal and Ahnell 1964). Saunders (1965) associated low standing crops of brook trout with increased sedimentation. Hall and Lantz (1969) in their Alsea drainage studies in Oregon found that a five percent increase of materials in the spawning substrate smaller than 0.033 inches in diameter caused a decrease in the survival of emergent coho salmon fry (Oncorhynchus kisutch). Aquatic habitats having a low percent of gravel and rubble and a large percent of fine sediment, support low species diversity and a small biomass of aquatic insects (Wene and Wickliff 1940, Fennack and Van Gerpen 1947, Mackay and Kalff 1969, Brusven and Prather 1971). Burns (1971), however, found biomass was not significantly correlated with the volume of fine sediments in the streambed.

Relationships between quality and carrying capacity of habitat have been investigated in streams not altered by man (Allen 1949,

Onodera 1962, Bjornn 1971, Chapman and Bjornn 1969, Lewis 1967, and Stewart 1970).

Lewis (1967) measured 6 physical characteristics of 19 pools in a trout stream in Montana and found they accounted for 77 percent and 70 percent of the variation in number of brown and rainbow trout, respectively. Cover was the most important single factor influencing distribution of brown trout. Fast water pools were most attractive to rainbow trout.

Stewart (1970) determined 15 physical characteristics of 41 study sections of a small trout stream in Colorado. Weights of brook trout and rainbow trout over seven inches are determined per study section, and were used as the dependent measures of carrying capacity. For both species, mean depth was the single variable of first importance, and the combination of several categories of hiding and protective cover proved to be highly correlated with the distribution of density of brook trout but not rainbow trout. Shuck (1945) reported that volume and depth of water significantly affected population density of brown trout. The importance of stream depth was further supported by the work of Inger and Chin (1962) and Ruggles (1966).

Shetter and Leonard (1942) found that repeated seining in small streams was only 80 percent efficient. Larimore and Smith (1963) discussed the bias of the electric shocker as a capture method. Reid (1961) has stated that the choice of physical factors to be analyzed is difficult because environmental variables in streams are typically correlated and confounded with one another. Chapman (1966) stated that physical habitat is a major

influencing factor that determines population density and establishes the criteria governing population density. Sheldon (1968) determined that distribution and diversity of fishes in Owego Creek were controlled by structural features of the habitat.

Lewis (1967) concluded that surface area, volume, average depth, average current velocity, and percent of cover accounted for variations in numbers of trout. Burns (1971) found that, in selected California streams, biomass per unit of living space from one summer month to the next or one year to the next was an adequate indication for only gross changes. He theorized that physical and chemical factors would not prove to be useful factors for predicting carrying capacity, since only the living space variable correlated significantly with biomass.

Saunders and Smith (1955) found that pools with brush cover were a dominant factor in increasing standing crops of older brook trout in a small stream. Lewis (1967) concluded current velocity and total cover were the most important in determining fish production. Hunt (1971), in conflict with Chapman (1966), noted that the carrying capacity of trout was poorly correlated with the surface area but that an increase in permanent cover on banks increased biomass of fish. Butler and Hawthorne (1968) found that certain fish species utilized open areas with rainbow trout using open areas more than brown trout (Salmo trutta). Ruggles (1966) found that silver salmon fry avoided shaded areas and their density decreased when artificial cover devises were added. Needham and Jones (1959) noted that rainbow trout strongly preferred sheltered areas. Stewart (1970) asserted, however,

that cover was highly correlated with density of brook trout but not rainbow trout. Boussu (1954) confirmed that the removal of undercut banks and brush from a section of stream caused a decrease in the number of weight of resident trout; increases followed application of the cover.

Sheldon (1968) found that numbers of fish species were less in headwaters and they increased in the downstream direction. Margalef (1963) stated that increases in maturity were always downstream, which means that increased waterspace may be a factor. Nilsson (1956), Hartman (1965), and Fraser (1969), found that two or more species of fish used specified habitats more efficiently than did one species alone.

Chemical Studies

Livingstone (1964) demonstrated that, throughout the world, river water is extremely variable in its chemical composition, and that rain or snow have considerable chemical variation. Most of the solutes in landbound waters, however, are from terrestrial sources and not precipitation (Gorham 1961). Gorham suggested that the environmental factors that determine the chemical composition of river water are climate, geology, topography, vegetation, and time. Durum, Heidel, and Tison (1960) studied streams in diverse regions of the world, and inferred that dissolved load in the water is relatively less where land slope is high.

In reviewing studies relating water chemistry to fish-carrying capacity of streams, authors have difficulty in finding any significant correlation. McFadden and Cooper (1962) pointed out a correlation between brown trout biomass and water conductivity but

but could show no statistical significance. LeCren (1969) could find no correlation between the production of brown trout and Atlantic salmon (Salmo salar) and the calcium content of English streams. Burns (1971) failed to find any significant correlations between relative biomass and total solids, total phosphate, or total alkalinity.

Kunkle and Neiman (1967) correlated high flow periods with water temperatures, turbidity, suspended sediment, and dissolved solids. Minimum pH units occurred near peak flow periods; and pH decreased 0.1 to 0.2 units per 1,000 feet increase in elevation. Powers (1929) verified that a general decrease in pH accompanied increases in elevation in the Smoky Mountains. The pH also rose from summer to autumn. Kunkle and Neiman (1967) reported that dissolved solids were not common to all sites.

Classification Studies

Many systems have been presented for classifying aquatic environments within ecosystems, but they usually pertain to certain aquatic types or are too broad in meaning to be of value. Depending on the authors, the systems vary as to the factors used to describe the different aquatic types. Hydrochemical properties, stream size, location, aquatic organisms, or elevation have served as criteria for classification.

The classification systems for lotic habitats are varied, uncertain, and unreliable; few have had anything beyond local acceptance. Illies and Botosaneanu (1963) have briefly reviewed the widely scattered literature bearing on classification of lotic habitats and pointed out the several basic kinds of classification systems. Ohle (1937) used only the calcium

content of the water to classify streams while Knight and Gaufin (1967) worked out a classification system based on the distribution of species of Plecoptera. Illies (1961) based a classification system on eight water zones, from zone one (springs) to zone eight (brackish); Huet (1959) and Trautman (1942) used gradient and width to define faunal regions and to predict the distribution of individual species. Kuehne (1962) utilized the ranking system of Horton (1945) to describe the fish fauna of Kentucky streams; Shelford (1913) explained the distribution of fishes in terms of the geological concept of aging stream beds. Thompson and Hunt (1930) described the number of species of fish as being proportional to the area of drainage of the streams.

Ricker (1934) classified Ontario, Canada, streams in spring creeks, drainage creeks, slow trout streams, swift trout streams, and warm rivers. Elster (1966) in Europe used a "saproby" classification system as related to dissolved oxygen content. Shelford (1913) classified streams very similarly to Ricker. Moon (1939) favored the "erosion-deposition" concept (channel fill-channel scour) in substrates of streams. Odum (1956) used a ratio between autotrophy and heterotrophy based on primary productivity measurements; Kuehne (1962) based his classification on fish distribution.

To date the classification systems have been of little value in applications relevant to land or water management needs. Pennak (1971) recently made progress, however, using classification systems based on variables that would be of value worldwide. He stated that swift streams in the Colorado Rockies, the Alps in Europe, the mountains of New Zealand, and the Andes, all of which are similar chemically and physically, usually also have faunas

that are strikingly similar. Pennak based his classification on physical and chemical parameters that can be universally determined.

Land Uses

Other authors have identified aquatic environmental changes that could be ascribed to watersheds having been disturbed by logging and the construction of roads. Most such studies, however, have been conducted during or immediately after the disturbance. Fisk et al. (1966), who studied two streams disturbed by logging and road construction, showed that undisturbed sections had about five times more fish weight than did disturbed sections. Kopperdahl and Burns (1970) found that conditions in some California streams generally were suitable for salmonids during and after logging. They reported no abnormal concentrations in hydrochemical conditions other than high carbon dioxide, where logging debris was decomposing. Hall and Lantz (1969), in their Alsea studies, however, found that resident cutthroat trout within logged areas were reduced by 75 percent the first year and migratory cutthroat trout were reduced substantially the first two years.

STUDY AREA DESCRIPTION

Approximately 397 square miles along the upper 52 miles of the south fork of the Salmon River drainage in west-central Idaho were included in the analysis. The area's topography ranges in elevation from 9,000 feet around the headwaters, to 3,700 feet at the mouth of Circle End Creek. Most slopes are steeper than 40 percent, and slopes over 65 percent are common (Jensen and Finn 1966).

Fishery

The drainage in question has historically contained Idaho's largest salmon run, composed entirely of summer chinook salmon, a race now reduced in abundance in the Columbia River system (Richards 1963). Steelhead trout and fluvial cutthroat trout, which occur within streams, have been diminishing in both range and numbers.

The river, especially after 1940 as fishing for chinook salmon and steelhead trout gained in popularity, has been subject to heavy fishing pressure during chinook salmon and steelhead trout seasons and light pressure on rainbow trout, cutthroat trout, Dolly Varden, and mountain whitefish. The tributaries experience little fishing pressure.

Most of the chinook salmon spawn in the main stem of the south fork of the Salmon River; steelhead trout spawn mainly in the tributaries. The lower portions of the major tributaries are used

occasionally by chinook salmon for spawning and rearing, but fish populations there are dominated by rainbow trout (Appendix A, Table 5).

The main river channel includes some low gradient areas, while the side tributaries have higher gradients that are too steep for high production of salmonids. The average elevation of the tributary stream channels is 5,653 feet; the channel range from 4,370 to 7,407 feet. The tributaries are therefore classified as high elevation coldwater streams.

Climate

The climate of the study area is characterized by hot, dry summers and cold, moist winters; 45-90 percent of the 26 inch mean annual precipitation falls as snow. Frontal rain storms, of long duration (one to four days), produce as much as 10 inches of precipitation and are a critical factor in flooding and landslides during winter and spring. Maximum precipitation occurs during December, January, and February, with a secondary peak in May and June.

Geology

The study area is in the southern portion of the Northern Rocky Mountain physiographic province and is located entirely within the Idaho Batholith. This large intrusive granitic batholith covers about 16,000 square miles in Central Idaho and Western Montana (Figure 7).

The combination of soil characteristics, steep topography and high climatic stress. create extreme erosion hazards. The soils in the study area differ greatly among themselves as to

degree of decomposition from weathering (Figure 8). Specific degrees of weathering are associated with broad geomorphic types that have a similar genesis, these types are described in Appendix B, Tables 6 and 7.

The watershed of the south fork of the Salmon River displays a large array of geomorphic types resulting from land-forming processes since the rise of the batholith. The main shaping forces have been streams, glaciers, and mass-wasting processes with high natural geologic erosion, especially at the higher elevations. Faulting, folding, and uplift have also played an important but less extensive role in the land forming processes.

The strongly glaciated lands were created by alpine glaciation, the major recent landforming activity which rarely occurred below 5,000 feet elevation. Cliff glaciers created cirques or amphitheaters at the heads of glacial valleys, and the valley glaciers formed in V-shaped canyons originally cut by streams. As alpine glaciers flowed, they moved soil and rock from the canyon and redeposited it; this created U-shaped canyons with steep slopes. Some large valley glaciers intercepted and undercut smaller tributary glaciers. This created hanging valleys with sections of their streams being almost vertical in gradient (Figure 9). The intensive glacial erosion of the high country has caused extensive corresponding glacial deposits in lower elevations.

Figure 7. The location of the Idaho Batholith.

Figure 8. The mechanical disintegration of granitic bedrock, known as granular exfoliation. Note accumulation of materials at toe of cut slope. Disintegration of bedrock is typical in disturbed lands in the fluvial geologic process group that produces coarse soils. Such soils, upon entering stream, become coarse sediments.

Figure 9. Strongly glaciated geologic process group with rocky ridge geomorphic tvne (113) in the background. Note the U-shape of the valley in the foreground, which disappears into a larger U-shaped glaciated valley, forming a hanging valley.

METHODS AND EQUIPMENT

Evaluation of the Physical Fluvial Aquatic Environment

The physical aquatic environment survey used with modifications, the methods outlined by Herrington and Dunham (1967). The modifications were made to increase sample sizes in small drainages and to quantify additional physical conditions as described later. The aquatic evaluation methods satisfactorily quantified most of the variables, as water depths rarely exceeded 48 inches and water velocities were never excessive for instream work. The clear water with low flows (July-November) offered excellent conditions for observation measurement. The studies were conducted from 1970 through 1972.

Stations

Most of the major tributaries within the 397 square mile study area were inventoried. The 38 major tributaries, accounting for 135 stream miles, were inventoried with an average of one study transect for every 93 yards of stream. All streams were sampled from mouth to headwaters until ephemeral stream conditions were encountered.

Each stream station to be physically analyzed was selected randomly, marked on an aerial photograph (1-15,000), and then located on the ground. The first transect of each station was located 100 feet upstream from the photographic location to avoid any bias resulting from locating the stations with use of aerial photographs.

Sample sizes for all the variables that were described or compared are listed with data summaries. Confidence intervals at the 95 percent confidence level are listed for variables relating to comparisons of aquatic environments with geomorphic conditions (geologic process groups and geomorphic types).

Transects

A transect is defined as an imaginary line marked with a measuring tape that runs from bank to bank at a 90° angle to the centerline of the stream. Some streams or segments of streams within geomorphic types were not sufficiently long to permit locating the minimum number of 30 transects by using the station method. In such cases, the stream was divided into 30 equal intervals with a transect representing each interval. The distance between transects depended upon stream length. Random stations were established on streams over one mile in length with each station including a cluster of five transects with 50-foot intervals.

The following measurements and conditional factors were recorded:

1. Stream, pool, and riffle widths to the nearest foot.
2. Four stream depths at equal intervals across the stream to the nearest inch.
3. Ratings, locations, and features of pools.
4. Stream channel surface material classifications.
5. Cover, conditions, and types of streambanks.
6. Channel elevations and gradients.
7. Geologic process groups and geomorphic types.
8. Stream order.

9. Whether the watershed was disturbed or undisturbed.

10. Fish species, their numbers, and the lengths of fish occurring in selected streams between transect one and transect two.

Materials of the channel

The composition of the surface materials of streambeds was determined by measuring directly with tapes or rods. A given transect of each stream channel was divided into one-foot intervals, and the dominant surface material determined the classification of each one-foot division (Table 1).

Table 1. Classification of stream channel materials.

Particle Diameter Size		Substrate Classification
12	inches and over	boulders
3	inches to 11.9 inches	rubble
0.19	inches to 2.9 inches	gravel
0.18	inches and less	fine sediment

Evaluations of pools and riffles

Stream areas were stratified as either pool or riffle. The pools then were classified as to suitability as fish environment based on the criteria outlined in Table 2. Widths of riffles and pools were measured to the nearest foot and these measurements equaled the width of the stream at that point.

Streambanks

Conditions, type and cover of each streambank where it was intercepted by each transect were rated in accordance with Table 3.

Streamside condition and the cover that influenced the stream and its banks were determined by evaluating the dominant influencing vegetative type or exposed condition for 50 feet upstream and 50 feet downstream from where the transect intercepted the bank. Definitions of streamside types refer to habitat types at the intersection of each transect with the banks.

Elevation of streambed

Station and transect elevations were read from a hand-held "Thommen" altimeter that was set each morning at an official USGS elevation marker. Transects in areas mapped to 40-foot contours were checked against the altimeter readings for any needed adjustment. The estimated elevation error per station is within $\pm$ 40 feet.

Gradient

Channel gradients were recorded at each station with a hand-held clinometer and equalled the average gradients over each entire 200-foot channel section.

Width and depth

Stream width values refer to surface water widths measured perpendicular to the flow of the stream. Average station depths were obtained from four equal-distance measurements.

Order

Stream order was determined by methods originally developed by Horton (1945) and later modified by Strahler (1952-1957).

Table 2. Pool quality rating guide for streams in the study area.

Pool			
Quality Class No.	Length or Width	Depth	Shelter[1]
1	greater that a.c.w.[2]	2' or deeper	abundant[3]
	greater than a.c.w.	3' or deeper	exposed[4]
2	greater than a.c.w.	2' or deeper	exposed
	greater than a.c.w.	2'	intermediate[5]
	greater than a.c.w.	2'	abundant
3	equal to a.c.w.	2'	intermediate
	equal to a.c.w.	2'	abundant
4	equal to a.c.w.	shallow[6]	exposed
	less than a.c.w.	shallow	abundant
	less than a.c.w.	shallow	intermediate
	less than a.c.w.	2'	intermediate
	less than a.c.w.	2' or deeper	abundant
5	less than a.c.w.	shallow	exposed

1. Logs, stumps, boulders, and vegetation in or overhanging pool, or overhanging banks.
2. A.c.w. = Average channel width.
3. More than 1/2 perimeter of pool has cover.
4. Less than 1/4 of pool perimeter has cover.
5. 1/4 to 1/2 perimeter of pool has cover.
6. Approximately equal to average stream depth.

Table 3. Numerical ratings used to classify streambank cover, condition, and type.

Cover*		Condition**		Type***(Example)	
forested	2.0	excellent	2.0	sod, root, log	2.0
brush	1.5	good	1.5	brush, rubble	1.5
grass	1.0	fair	1.0	grass, gravel	1.0
exposed	.5	poor	.5	fines, road fill	.5

*Cover = type of vegetation dominating the streambanks or lack of.

**Condition = Stability of the streambank to water flows.

***Type = A habitat type that can be a single character or combination of characters.

Fish Collection

Explosive prima cord assured collection of 100 percent of the fish population within each sample area. Prima cord detonates at over 21,000 f.p.s., essentially instantaneously (Figure 10). This explosive has a potential for a total kill of fish within 10 to 15 feet of the cord providing no major blocks occur between the explosive and the fish (Table 4).

After locating the stream area to be sampled, a 0.125 to 0.225 inch mesh net was stretched across the stream on or very near transect one to block fish from moving out of the sampling area (Figure 11). To insure total fish collection, a minimum of one 50-foot length of prima cord was used. Other prima cord strands were sometimes needed in a channel to be certain that major under-

water blockage points had explosive force on both sides.

Table 4. Number of strands of prima cord used in various stream widths and depths to assure complete fish mortality.

	Channel Width (feet)				
	8	8-15	15-20	20-25	25-30
6	1	2	2	2	3
6-10	1	1	2	2	2
10-15	1	1	2	2	2

After each explosion, all dead fish were recovered from the streambottom; then the net was carefully lifted and examined for fish. All collected fish were identified and measured from tip of snout to end of longest lobe of the caudal fin. The total number of fish per area and the average of the total lengths of all fish collected per station or stream variable were the values used in the analysis.

A total of 2.75 miles of stream area were sampled using about four miles of prima cord. This allowed documentation of fish populations at 291 stations. The low concentration of total dissolved solids (60 ppm) in stream waters meant that more reliable information could be obtained with explosives than by using electrical fish collecting equipment.

Classifying Disturbed and Undistrubed Areas

Disturbed areas were defined as those that had been logged or that contained roads. The disturbed areas of each watershed were

Figure 10. Prima cord explosion in a shallow stream area. A large part of the force goes into the atmosphere, but the underwater killing effectiveness is still high.

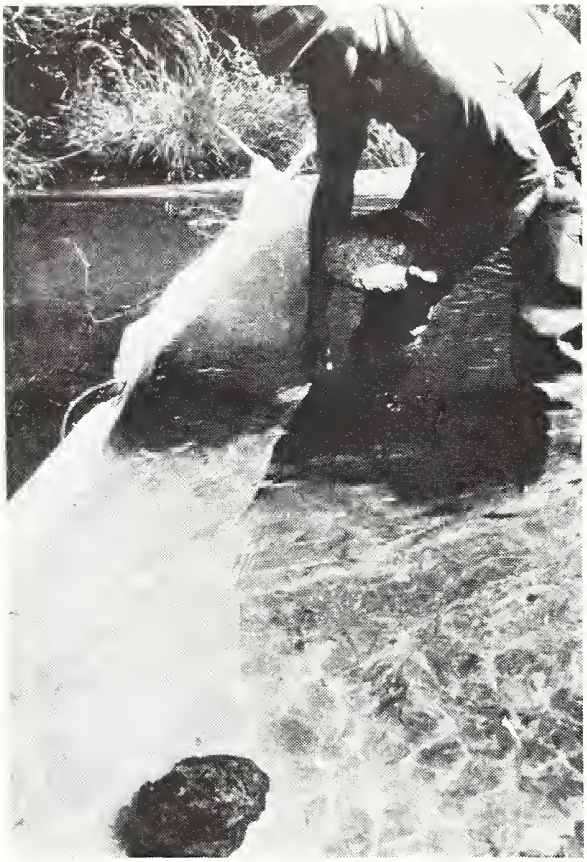

Figure 11. The downstream barrier net strained all water moving out of each sanoke area before and after each explosion to assure total collection of all fish.

mapped by using map overlays of logging sale boundaries and updated Forest Service maps of areas with roads. The remainder of the study area was classified as undisturbed.

Land Classification

The area had been stratified by soil scientists into four geologic process groups and then further stratified to 26 geomorphic types--the lowest type of classification used in this study (Appendix B, Tables 6 and 7). These geomorphic types were mapped and overlays used to define the geologic process group or geomorphic type relevant to a given stream or stream area, stream station, fish collection area, and stream transect.

Geomorphic types are part of a system proposed by Wertz and Arnold (1972) that contains the following categorical levels in descending order of heirarchy:

7. Physiographic province
6. Section
5. Subsection
4. Geologic process group (landtype associations)
3. Geomorphic type (landtype)
2. Geomorphic phase
1. Site

Hydrochemical Sampling

Water samples were collected in inert plastic bottles, which had been stripped with reagent spectrometric grade nitric acid. The analysis was conducted by a graduate certified chemist from the Idaho Department of Environmental and Community Services, using modern equipment and following the guidelines outlined

in Standard Methods (1971).

Computer Analysis

All information was key punched on computer cards and transferred to magentic tapes. The CUMDIS (cumulative distribution) statistical program (package 52) was used to generate cumulative frequencies, means, and standard errors about predetermined variables. The information collected in the field was sorted into predetermined grouping; basic statistical information was then derived for the variable in each grouping. The number of observations from the field collections in many groupings exceeded the storage capability of the computer. The data were therefore broken into subsets or groups and the sums and sums of squares printed for each group. Groups could consequently be combined with calculators. In group calculations the X^2 values, X values, and n values were determined and summed. These values were then inserted into the formula.

$$S = \sqrt{\frac{\sum_{i=1}^{k} X_i^2 - \frac{(\Sigma X_i)^2}{n}}{n - 1}}$$

where,

$X_i^2 = \Sigma X^2$ for the the group

$X_i = \Sigma X$ for the th group

K = the number of groups

n = the total number of observations in all groups,

and the standard deviation calculated. The other statistical values, as means, were calculated bv standard methods. Once standard deviation was determined, confidence limits were placed about the means using the formula,

$$CL = \frac{S}{\sqrt{n}} \quad X\ t_{.05,\ n-1}.$$

All confidence limits were calculated by using t. values at the 95 percent level. The STAPTPAC/LIBRARYA unit at Utah State University was used to run the inverted matrix multivariate analysis.

STREAM ENVIRONMENT

Hydrological Conditions

Widths and depths of channels

Sample means representing 32,997 linear feet of stream channel were analyzed. Results indicated that as channel widths increased in the study streams, channel gradient, percent of gravel, channel elevation, streambank condition, and streambank type rating all decreased. Although not as definitely, percent of fine sediment and percent of pool area also seemed to decrease (Appendix C, Table 8). As width of channel increased in the study streams, stream depth, percent of boulder, and percent of riffle increased. The relationship of stream width to other variables of stream structure (depth, elevation, order, and channel substrate) closely followed findings by other authors (Leopold, Wolman, and Miller 1964).

Relations between stream depths and aquatic variables also closely followed findings reported by other authors. As stream depths increased in the study streams, channel gradient, percent of gravel, percent of rubble, channel elevation, and percent of riffle decreased with percent of riffle decreasing to nearly zero (Appendix C, Table 9). Percent of channel in boulders also tended to decrease with increasing depths. As with increasing depths, width of stream, quality of pool, percent of fine sediment, and percent of pool area increased, with percent of pool increasing to nearly 100 percent of the area.

Pools rated very poor in quality in areas of the stream averaging 2.0 inches in depth. As stream depths increased, pool quality ratings increased, and in stream areas averaging over 29 inches in depth, pool quality ratings were excellent. As stream widths increased, fine sediment in the channels decreased. As stream depths increased, however, the fine sediment ratings increased. As stream depths and widths increased, the environmental quality ratings of the streambanks decreased; but in larger and deeper streams, the bank environments play a lesser role in the environment of most aquatic organisms. For every unit the average study stream gained in depth, it gained from about 12 to 25 units in width (Figure 12) demonstrating that most streams broaden more readily than they deepen.

Channel gradient

In mountainous areas, except through depositional lands, streams flow close to bedrock, which influences longitudinal profile. The block (normal) faulting and glacial stairways that occurred in the headwaters of most of the study streams also eliminated grading in all sections of these streams. In the case of glaciation, the channel of the stream is often subdivided into a number of giant steps, and streams often confluence discordantly rather than accordantly as is the usual case in fluvial lands.

Geologic processes, such as glaciation, strongly influence the gradient of a stream channel, but the relationship of gradient to variables of stream structure usually followed what other authors have demonstrated (see Aquatic Literature Review). Stream channels with gradients less than 6.9 percent made up 69 percent of

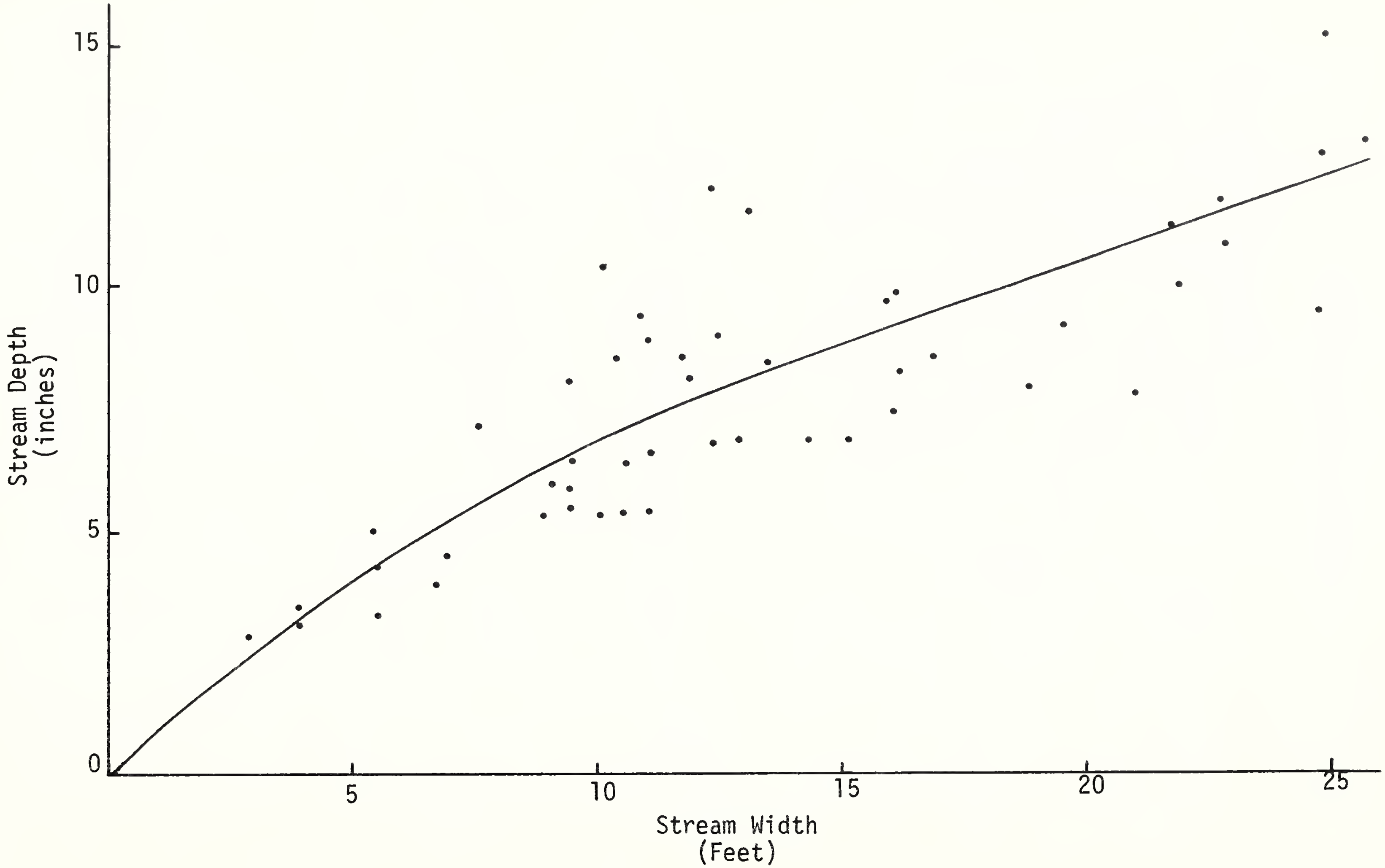

Figure 12 . The relationship between depth and width of the stream using the average stream values.

the channels studied (Appendix C, Table 11). Only about three percent of the stream channels are above 19 percent gradient. The interpretation of variable means, unless otherwise stated, was based only on channel gradients between zero and 20 percent.

As channel gradients increased in the study streams, stream widths, stream depths, and pool quality ratings decreased; however, percent of pool and percent of riffle ratings, as well as channel elevation, showed no trends with increasing gradient. Pool areas dominated riffle areas in channels having less than a two percent gradient, but above three percent, riffle areas were dominant. In classes of gradient above 25 percent, riffle area classifications dramatically increased while percent of pool designations decreased (Figure 13).

Channel gradients between one and three had substrates dominated by fine sediment, but above three percent, boulders became the dominant substrates with percent boulder steadily increasing as gradient increased (Figure 14). The curve representing percent of fine sediment decreased rapidly as channel gradients went from zero to five percent but beyond five percent the decline was very slow.

In the tributaries, when the complete range was considered, rubble ratings showed no discernible correlation with gradients, but content of gravel decreased with increasing gradients. Cover along the sides of the streams did not change with gradient changes, but streambank stability ratings increased with increasing gradients.

Conditions of pool-riffle

One of the requirements for the existence of pools and riffles

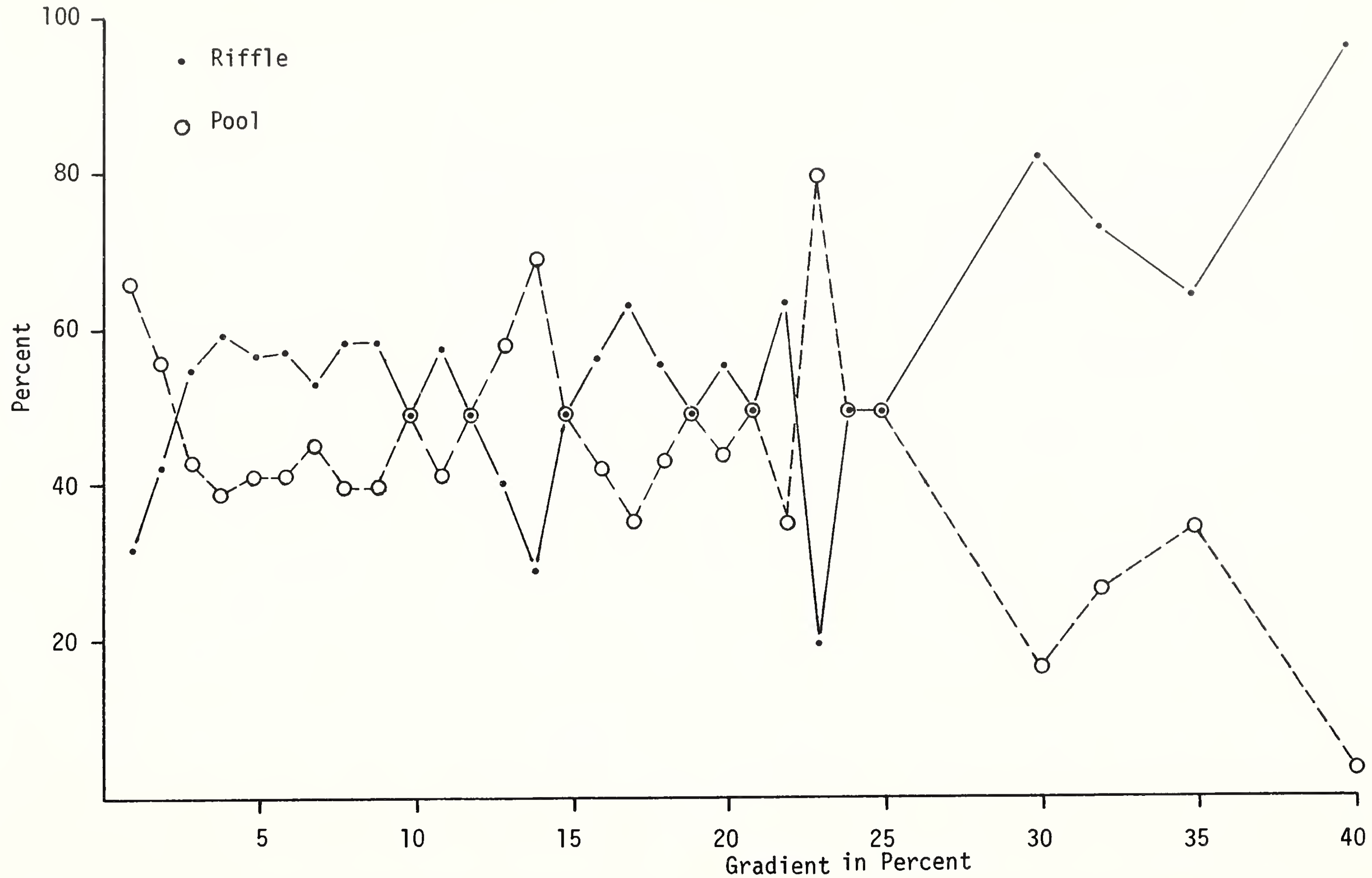

Figure 13 . Relationship of percent of riffle and percent of pool to gradient of the stream channel.

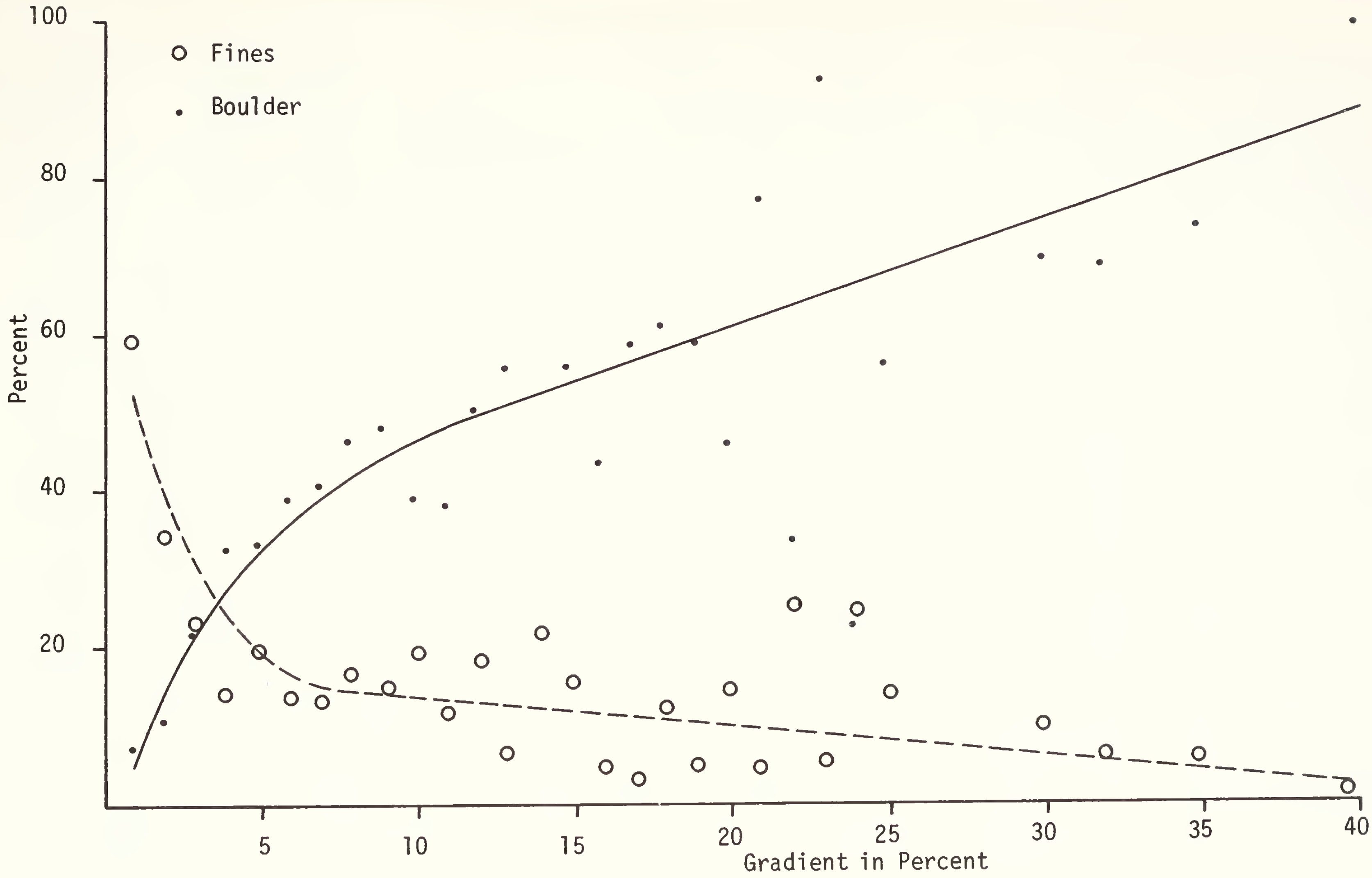

Figure 14 . Relationship of materials of the stream channel (percent of boulder and fine sediment) to channel gradient.

in non-meandering streams appears to be some degree of heterogeneity in the size of bed material (Leopold, Wolman, and Miller 1964). In the study streams that were dominated by boulders, the size of the material itself created pools regardless of heterogeneity.

As pool quality ratings decreased in the study area, percent of rubble values, channel gradients, and percent of riffle ratings increased, whereas the channel widths, stream depths, and percent of pool values decreased (Appendix C, Table II). Materials of stream channels and pool quality ratings were definitely related. The higher the percentage of fine sediment in the surface substrate of a channel, the better the quality of pool; and the higher the percentage of boulder, the lower the pool quality. Pool quality ratings increased with increasing stream depths. Deeper pools evidently tend to trap and contain fine sediment. Pools dominated by boulders tend to be much shallower than pools with bottoms of fine sediment, as evidenced by the inability of small tributary streams to construct deep pools in channels composed of boulders and rubble. Areas of the South Fork of the Salmon River have a much higher competency and therefore can move boulders.

Streambank condition quality ratings increased as pool quality decreased, demonstrating that fine sediments lower the stability of streambanks. No relationships were found between increasing quality of streambank cover and increasing pool quality ratings.

Streambanks

The methods used to quantify aquatic structures and surrounding influences in this study were satisfactory except for pool ratings,

aquatic vegetation values, and streamside environments. The aquatic vegetative information was discarded because the crude methods available did not allow adequate description or quantification. The methods used to evaluate streamside cover and streambank condition were of some value to interpretations, but were inadequate for complete description and quantification.

Streamside environment ratings involved 4,964 observations and 270 miles of streambanks. Almost all the ratings were good to excellent in terms of adequate vegetative cover and general stability (Appendix C, Tables 12, 13, and 14). As streamside cover, conditions, and type ratings increased in quality, stream depth, percent of fine sediment, and pool quality decreased. As the streambank environments increased in quality, channel, gradient, percent of pool, percent of rubble, and percent of boulder values increased; percent of gravel did not correlate.

As quality ratings for condition and type of streambank increased, the stream width decreased; but as streamside cover increased, width also unexpectedly increased. Although stream width and streamside cover did not show the expected relationship, the overall relationships between streamside environment and the other physical variables of the stream were uniform.

Stream Order

First- and second-order streams contribute 78 percent of the stream mileage within the study area but have little fishery value. The main value of these streams is in their delivery of water and possibly as a source of food to higher stream

orders (Appendix C, Table 15). Stream orders three, four, and five provide upstream spawning and rearing areas for migrating salmonids.

The drainage basins of first-order tributaries usually had steep-sided, V-shaped, incised channels. In the glaciated lands with modified watershed, however, the first-order tributaries are in steep-sided, U-shaped valleys and do not have incised channels.

The relationship between increasing stream order and stream structure was as predicted. As stream order increased, width, depth, and percent of rubble ratings increased, while percent of pool, percent of gravel, gradient of channel, and elevation of channel values decreased. The remaining stream variables showed no correlation.

Channel Elevations

Stream channel elevations varied from 3,600 to 8,000 feet, with certain stream structure variables (channel gradient, percent of pool, and percent riffle) showing no relationship to elevation (Appendix C, Table 16). The lowest elevation class (3,600 - 3,799 feet) had high channel gradients, but this was mainly because these stream channels were located in strongly dissected mountain lands adjacent to oversteepened canyon lands. Riffle areas dominated streams located at from 3,600 to 6,000 feet, but in streams above 6,000 feet, pool areas were dominant. Pool quality ratings showed no direct correlation with channel elevations except that the better quality of pool occurred in the middle elevation streams (4,600 to 6,400 feet). Stream widths and depths decreased as elevation increased simply because streams have less discharge at higher elevations.

No clear relationship existed between channel elevation and percent of either boulder or fine sediment making up the substrate of the channel. Glaciation in the higher elevations was predicted to have resulted in larger channel substrates, but the percent boulder ratings decreased as channel elevation increased. This could be due in part to the lack of boulder material in the cryoplanated lands. Gravel increased, and rubble decreased as channel elevation increased; quarrying in the headlands and avalanches possibly accounted for the increase in gravel.

The average composition of the substrate in stream channels between 5,400 and 6,599 feet was well balanced. Below and above these elevations, however, the average composition of channel substrates was unbalanced. Streambank environments showed no definite changes as elevations increased or decreased except that tree cover seemed to dominate streambanks more in higher elevations than in lower elevations.

Summary - physical conditions

Most components of the aquatic structure were related which helped explain why the more productive aquatic environments were in the lower elevation areas. As stream channels decreased in elevation, so did gradient, while width and depth increased. This provided more water surface and wetted channel, thus offering more potential spawning and rearing space. As stream depth increased, percent of stream in pool and pool quality ratings increased--again, conditions that favor greater fish population densities.

The relationships among most features of stream structure generally followed what other authors have reported, but the controls exercised by certain types of geomorphic process (glaciation), led to some nonconformities. The relationship between gradient of channel and elevation of channel was not uniform throughout all landforms. As stream elevations increased, percent of gravel in the channel increased and rubble decreased. Riffle area dominated streams located from 3,600 to 6,000 feet, but pool areas dominated above 6,000 feet. The higher the percentage of fine sediment in the stream channel, the higher the pool quality; the higher the percent of boulder in the stream channel, the lower the pool quality. This can be explained in terms of pool quality ratings increasing as stream depth increased. Small streams cannot dig deep pools in boulder substrate; and fine sediments accumulate during low flows in the bottom of large quiet pools.

No clear relationship developed between stream elevation and ratios of boulder to fine sediment in the channel. This could be due to lack of uniformity between landforms when compared to the relationships between elevation to gradient. Also, as stream widths increased. percent of fine sediment in the channel decreased. As depth increased, however, so did fine sediment ratings, which relates to the lower energy in flows with increasing depth.

For every unit the average stream gained in depth, it gained from 12 to 25 units in width, demonstrating that most streams broaden more easily than they deepen. Size of particle materials in the streambottom determined the characteristic of longitudinal profile or vice versa. As channel gradients increased, the

percentages of rubble and boulder increased, while sand and gravel contents decreased. A definite inverse relationship prevailed between amount of boulder and amount of fine sediment in stream channels.

As would be expected, pool quality ratings were very poor when the average stream depth was two inches or less. By a 29-inch average depth, however, pool quality had become excellent. Area of pool ratings exceeded riffle areas in stream channels of less than a two percent gradient, but above three percent, riffle areas became dominant. Channels with gradients of between one to three percent had substrates dominated by fine sediment, but beyond three percent, boulder became the dominant substrate and continued to increase steadily as gradient increased. Percent of fine sediment in a channel decreased rapidly as the channel gradient increased from zero to five percent but beyond five percent the decline was slow.

Biological Conditions

Fish populations

Poor access, small trout, and higher quality fishing in surrounding areas equate with light fishing pressure on the study streams. Fish mortality in undisturbed watersheds is mainly due to naturel cause and standing crops thus provide a measure of fish populations under natural conditions, and give unbiased estimators of the quality of the aquatic environment.

The study environments represented nearly natural conditions, but Burns (1971) has demonstrated that natural variations can occur

in numbers of trout from month to month and year to year, and thereby bias one-year or two-year studies. In 1971, standing crops averaged 3.5 fish per 50 feet of stream compared to 5.7 fish per 50 feet of stream in 1972. This difference, however, was understandable since the largest and most productive streams (Lick, Fitsum, and Buckhorn) were sampled in 1972. The fish populations of the study streams were quite stable during the two years of sampling.

Only Roaring Creek, sampled at six stations, failed to produce any salmonids. The remainder of the fish sampling effort demonstrated that salmonids had adapted themselves to almost all tributary streams in the study areas. The streams that produced the highest numbers of fish per unit of stream also contained more fish species.

Streams draining multiple geomorphic types had the highest standing crops of fish, while those draining single geomorphic types had much lower standing crops. This phenomena could relate to water space, however, because the more geomorphic types of a stream was draining, the longer and larger the stream tended to be.

Rainbow trout were the dominant species, possibly because the area contains both anadromous (steelhead trout) and resident species. Chinook salmon were second in numbers, and made unexpectedly heavy use of the small tributary streams for rearing their young. Dolly Varden were third followed by west-slope cutthroat trout. Brook trout, an exotic, were fifth, approximately equaling the indigenous sculpin. Mountain whitefish were seventh in numbers, with dace being found only in Cabin Creek. The dace in Cabin Creek

had probably moved out of Warm Lake. The category "Other Fish" includes those too damaged or too small for identification.

Rainbow trout appeared to be a depressant to Dolly Varden populations; streams having the highest populations of rainbow trout housed no or low populations of Dolly Varden. Sculpin were found only in combination with cutthroat trout in only two streams. Mountain whitefish occurred in streams where at least four other species of fish were existing. Brook trout and cutthroat trout co-existed in only one stream. Cutthroat trout tended to occupy those streams without chinook salmon and steelhead trout.

Streamside environment and fish. Fish population densities, based on population means, were higher in streams having grass and brush habitats (Appendix D, Table 17). Chinook salmon, Dolly Varden, brook trout, sculpin mountain whitefish and dace had higher population means along grass-dominated streambanks. Rainbow trout populations were higher in stream areas having streambanks dominated by brush. Rainbow trout used open areas more than did cutthroat trout, which tended to utilize timber types.

Populations of young-of-the-year chinook salmon were highest in the more open channels and the lowest in channels where tree cover dominated. This is partially due to salmon favoring the lower segments of tributaries (close to the river) which had higher areas of water surface per length of stream and lower channel gradients. Streambank cover explained 4 percent of the observed variation in total fish densities (Appendix H, Table 44 and Figure 15).

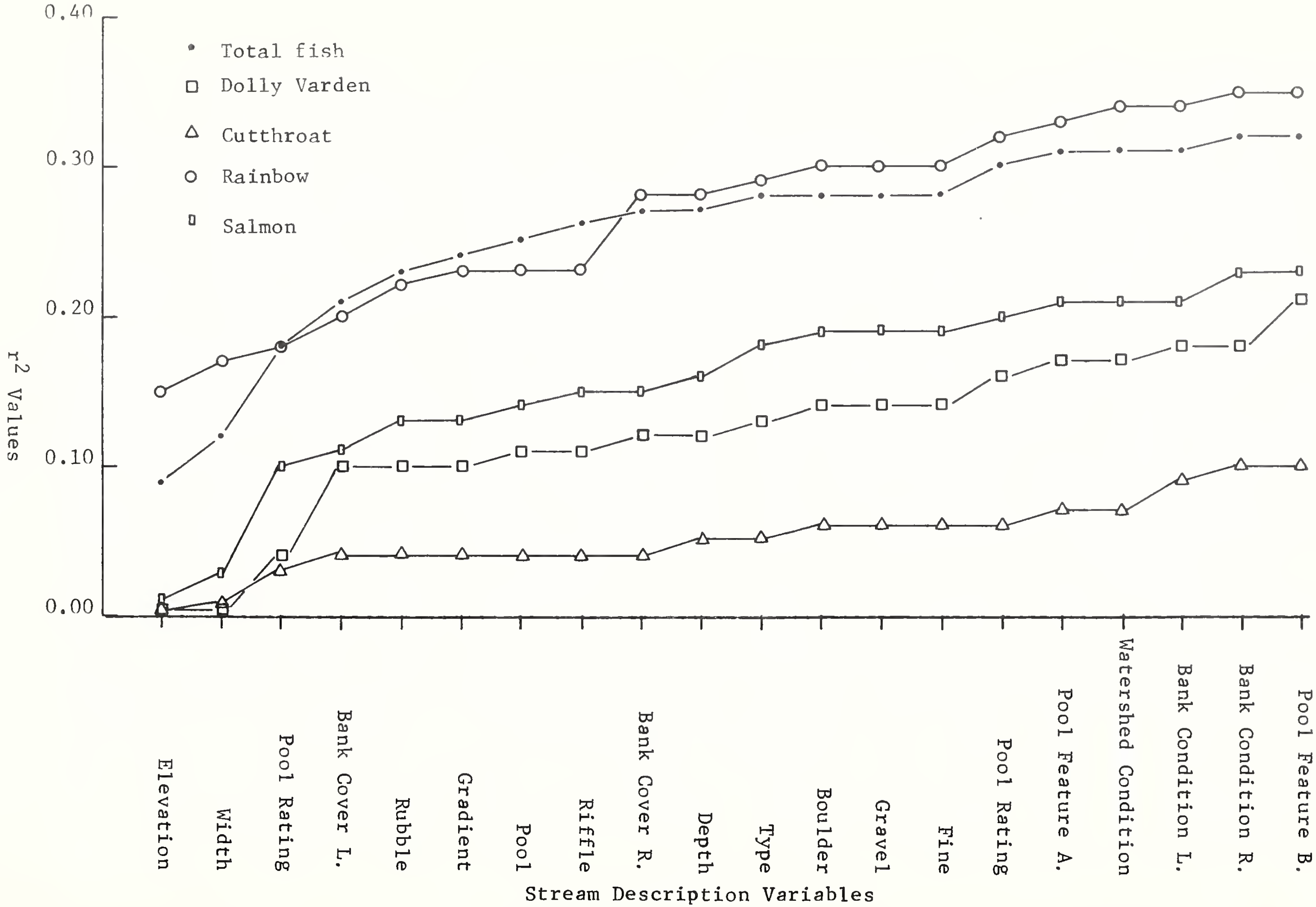

Figure 15. Explained observed variation between stream descriptive variables and fish species numbers.

Streambank condition ratings had no detectable influence and accounted for an insignificant amount of the explained variation of total fish standing crops (Appendix D, Table 18). Chinook salmon, cutthroat trout, Dolly Varden, sculpin, and mountain white-fish had about the same population means in areas of streams having unstable banks as in areas having stable banks. Densities of rainbow trout increased with increasing streambank quality while brook trout decreased. Streambank ratings were also poorly correlated with fish population densities and species composition.

Effect of channel materials on fish populations. Many authors have demonstrated that excessive fine sediment is detrimental to aquatic life (see Aquatic Literature Review). In this study, however, fine sediment was considered as the single influencing variable and results differed from those of authors who compared increased fine sediment as it affected the same area under temporal conditions. I compared the relationships of sediment to the environment mainly in terms of spatial conditions.

As fine sediment increased in the stream channel, stream depths, pool quality, and percent pool ratings increased, while channel gradients and elevations decreased (Appendix D, Table 19). These variables usually equate with increased fish numbers, and could bias or hide any effects the increases in fine sediment may have. The multivariate analysis, however, also indicated that the amount of fine sediment in the channel had no effect on any observed variations in fish population numbers. Although no trend developed between increasing fine sediment and the means of total fish popula-

tions, collected rainbow trout per sample did decrease as sediment increased, and brook trout appeared to increase. Dolly Varden and brook trout were the only species found in transect areas of stream channels containing over 70 percent fine sediment. No clear trend was identified between total fish populations or individual fish species with percent of rubble (Appendix F, Table 20), although rubble was the only substrate class that had explained variation (two percent for total fish numbers).

Diversity of fish species was reduced in areas of streams having more than 50 percent fine sediment, but reduced diversity was not the case in channel areas with more than 50 percent of rubble and boulder. Fish numbers, fish lengths, and fish species composition were not correlated with percent of boulder or gravel in the stream channel (Appendix F, Tables 21 and 22).

Pool and riffle relationship with fish populations - Pools of excellent quality had the highest population means and the highest fish lengths per sample area (Appendix D, Table 23). This higher population density was due, in part, to young chinook salmon utilizing the stream areas that had higher quality pools. Pool condition accounted for 8 percent of the chinook salmon's explained observed variation. Elser (1968) and Lewis (1967) demonstrated that deep-slow pools with large amounts of overhanging cover support the highest and most stable fish populations. Although the opposite was true for rainbow trout and cutthroat trout, for other species my data followed the Elser and Lewis findings.

Population density of rainbow trout and pool quality related inversely, as rainbow trout tended to occupy riffle areas that were combined with shallow pools (Appendix D, Table 24). Dolly

Varden, brook trout, sculpin, mountain whitefish, dace, and chinook salmon increased in population densities as pool quality ratings increased. Pool condition was third in importance in accounting for explained variations in total fish numbers.

Population means and explained observed variation demonstrated that pool formation factors were not significant determinants of the ability of a pool to support fish populations. The physical conditions of the pool itself exercise the more important influence (Appendix F, Table 25).

Densities of fish populations in relation to pool-riffle ratios were lower than the often quoted optimum pool-riffle ratio of 50/50. The highest total fish population densities occurred in areas of stream having 30 to 50 percent pool ratings. Study streams naturally contain infertile water (see hydrochemistry profile) and a lower pool-riffle ration could be conducive to higher fish populations as it would increase the food producing areas. Chinook salmon populations steadily decreased as percent of pool ratings increased, because they required relatively larger streams with less channel gradient in close proximity to the river.

Rainbow trout had lower population means in areas having either a high or a low percent of pool ratings. The highest population densities occurred in conjunction with a 50/50 pool-riffle ratio. Dolly Varden was the only species to demonstrate a definite mean population increase as percent of pool ratings increased. Cutthroat trout, brook trout, sculpin, and mountain whitefish did not show any marked trends. Pool and riffle only accounted for 2 percent of the explained observed variation and ranked seventh and eighth in importance.

Effect of channel gradient on fish populations - As channel gradients increased from two to four percent, mean fish numbers per stream length increased. As channel gradients increased above four percent, fish numbers declined steadily; no fish were collected when the gradient was above 25 percent. Fish accumulative length ratings per sample area did not always follow the same trends as fish numbers, in some cases increasing with increasing channel gradients (Appendix D, Table 26).

Young-of-the-year chinook salmon, utilizing the lower stream segments, peaked at four percent channel gradient. By contrast, cutthroat trout, mountain whitefish, and dace did not appear in sampling until four percent was reached. Rainbow trout numbers peaked at five percent gradient. This may have been due to steelhead trout spawning higher in the streams than chinook salmon. Cutthroat trout, which utilize higher elevation areas, did not peak in population numbers until about 10 percent channel gradient.

Dolly Varden numbers peaked at gradients between six and nine percent--a range in which rainbow trout populations were declining. Brook trout and sculpin numbers peaked at three percent gradients, and their populations declined as gradients increased above four percent. Dace were the first fish to disappear from the environment as channel gradients increased. Mountain whitefish were next to disappear from samples in conjunction with increasing gradient; they are more adapted to slower moving streams. Chinook salmon were not found where channel gradients were over 10 percent because they only utilize streams at the lower elevations.

Brook trout and cutthroat trout were not found in streams with channel gradients above 17 and 14 percent, respectively. Although cutthroat trout had their higher population numbers at higher

elevations than rainbow trout, rainbows were found in streams with gradients almost twice as high. Rainbow trout were the only species analyzed, for which gradients accounted for some explained variation. For unknown reasons, rainbow trout appeared to be better adapted to a much more extensive (and higher) range of channel gradients that were any of the other fish species.

Effects of stream depth and width on fish populations - Increasing or decreasing mean stream widths and depths showed some relationship to increasing fish population numbers and average fish lengths per sample area based on sample means (Appendix D, Tables 27 and 28). In the multivariate analysis, width was important in explaining variations among fish numbers per length of stream. Increasing depths and widths did not, however, have invariable effects on population densities. Cutthroat trout, Dolly Varden, brook trout, mountain whitefish, and dace had lower population means in the larger streams, which were dominated by rainbow trout and chinook salmon. Dolly Varden were the only fish found in the smallest streams, and cutthroat trout were collected only in stream areas less than 25 feet in width. Dolly Varden and cutthroat trout did not increase in numbers as stream widths increased. Brook trout were found in the average size streams but not in smaller or larger than average streams. Chinook salmon, cutthroat trout, and sculpin numbers showed no relationship to changing depths. Stream depth accountability for explained observed variations among all species was negligible.

Landform relationship with fish populations - Only eight of the 26 geomorphic types and three of the four geologic process

group, which is inherently unable to build good streams. The strongly glaciated lands are almost barren of fluvial fish, with fish only occurring in the glacial trough geomorphic type.

The depositional and fluvial lands supported almost all of the observed fish populations. The depositional lands were the most prolific although they accounted for only 10 percent of the area. Based on interpretations of sample means, the alluvial lands contained the highest densities of fish populations. Because of the extensive mileage of streams in the valley-train and dissected-mountain-slope lands, fish populations were larger in these two geomorphic types.

Chinook salmon, rainbow trout, cutthroat trout, Dolly Varden, brook trout, and sculpin were found in both the depositional and fluvial geologic process groups; rainbow trout was the only species found in the strongly glaciated geologic process group. Mountain whitefish and dace occupied only the alluvial geomorphic type within the depositional geological process group. Chinook salmon were found mainly in the alluvial and alluvial fan geomorphic types that had low channel gradients and were in close proximity to the river. Rainbow trout populations were rated mainly in the valley-train and dissected-mountain-slope geomorphic types. Sculpin preferred the lower gradient areas of streams in the depositional geologic process group; for some reason, however, they did not occur in valley train streams although this stream type was of major importance. The predominance of high gradients in the valley-train streams could have been a factor.

The west slope cutthroat trout, widely acknowledged to be a species declining in numbers and range, mainly occupied the valley-train lands which, at sampling time, had experienced no measurable

stress from land disturbance. Stream conditions in this geomorphic type were still natural, nevertheless the density of the cutthroat trout populations was lower than those of rainbow trout or Dolly Varden and only twice that of chinook salmon and and brook trout. The fact that the west slope cutthroat trout occupies only two geomorphic types could attest to the difficulty it has in competing with other native as well as exotic species. Brook trout, an exotic species, have had much more success in extending their range and numbers within the study area. The results emphasize the critical problems the west slope cutthroat trout confronts in holding its range and numbers as land uses become more diverse and when native or exotic species are artificially stocked.

Relation of channel elevation to fish populations - The lower the channel elevation, the higher was the density of the fish population per unit of length (Appendix D, Table 31). The average total length of fish collected per sample, however, did not follow this relationship. About 80 percent of the fish collected (84 samples) were in streams between 3,600 and 5,200 feet elevation and 20 percent of the fish collected (207 samples) were taken from streams between 5,200 and 8,400 feet in elevation. Aquatic structural conditions (depth and width) and water temperatures in the lower elevation areas are more favorable for fish. Elevation was most influential among the variables in accounting for explained observed variation in total fish numbers.

Dace were the first to disappear from sample collections as elevation increased; chinook salmon and sculpin followed.

Mountain whitefish were not found above 6,000 feet, brook trout were not taken above 6,400 feet. Areas of streams with elevations above 6,800 feet produced only cutthroat trout and Dolly Varden. Surprisingly, rainbow trout inhabited a wide range of channel gradients but disappeared from the samples once channel elevations exceeded 6,800 feet.

<u>Relation of stream order to fish populations</u>. As stream order increased, available water space and fish standing crops increased. As stream order increased, numbers of chinook salmon, rainbow trout, sculpin, and total fish increased per length of stream, while cutthroat trout and Dolly Varden populations decreased (Appendix D, Table 32). Streams classed as order four contained the most species. No species occupied all stream orders, although inadequate sampling in stream order one could bias this. Order on streams tended to be ephemeral and those with perennial flows were so small (average width seven feet and depth four inches) that they did not enter into the sampling program. Orders four and five contribute about 75 percent of the fish populations in the study streams but only make up 19 percent of the stream mileage.

Classing streams in granitic lands as to their "order" and frequency of occurrence can give the land manager information on an approximation of present and standing crops of fish species.

<u>Summary-fish populations</u>. The numbers and species of fluvial trout were determined in the study streams mainly by the structural condition of the aquatic environment. These high-elevation lands influenced the numbers and species of fluvial trout present by controlling the quality of the aquatic environments.

Many landforms do not create the conditions necessary to developing the environmental quality that fish require. Only eight of the 26 standardized geomorphic types and three of the four geologic process groups occurring in the area supported fish populations. The cryoplanated lands failed to produce fish, and the strongly glaciated lands were almost barren of fluvial fish life. Fish can survive in high-elevation, strongly glaciated and cryoplanated lands regardless of severe climatic conditions, but fluvial aquatic structural conditions in this area precluded survival. Chinook salmon, steelhead trout, and resident trout constitute a valuable resource mainly because of the incorporated depositional lands, even though they only make up 10 percent of the area.

Although the fish populations were concentrated mainly in two geomorphic types, only one stream in the study area was without fish. Most of the sampled streams passed through or were influenced by more than one geomorphic type. Streams draining multiple geomorphic types had higher standing fish crops and more species than did streams draining single types.

The physical variables -- stream elevations, widths, and depths, pool ratings, channel gradients, and streamside cover -- substantially influenced fish population densities and species compositions. Elevation could be less of a factor than it appeared to be superficially because decreases in elevation were so closely associated with increasing stream width and depth. The study data infer that increasing water space, which is associated with decreasing channel gradients and increasing water temperatures, had more influence on increasing the density of

fish populations than did other factors. Over 90 percent of all fish populations occurred in the lower 1,600-foot contour (3,600 to 5,200 feet elevations), with less than 10 percent in the upper 3,200-foot contour (5,200 to 8,400 feet elevations).

Fish species prefer certain habitat types, or they are more successful in competing under certain structural conditions. Sculpin, chinook salmon, brook trout, and mountain whitefish preferred lower gradient channels while cutthroat trout inhabited channels of higher gradient. Total fish population densities were highest in the grass-brush habitat types, with chinook salmon dominant in the grass type and rainbow trout dominant in the brush type. Cutthroat trout numbers were at their highest in channels with dominant tree cover.

Although total fish population density followed certain relationships with structural aquatic variables, certain species usually showed reverse relationships or no relationship at all. Cutthroat trout had high populations in the tree habitat type, although the total fish populations were highest in the grass-brush types. Rainbow trout numbers were inversely related to increasing pool quality, although most species had a direct relationship. As stream widths and depths increased, the total fish population densities increased. Cutthroat trout, Dolly Varden, brook trout, mountain whitefish and dace, however, had lower populations in the larger and deeper areas of streams, possibly because rainbow trout and chinook salmon dominated in these areas.

Stream conditions may favor the fish species that is classed as dominant, but it also appeared as if the dominant fish species

depressed other fish species. Rainbow trout was the dominant fish species throughout the study area, and where rainbow trout populations were high, Dolly Varden and cutthroat trout populations were low. Sculpin were found only in combination with rainbow trout.

It is the proper combination of aquatic conditions, not just one variable, that is significant in producing a fishery resource. One variable by itself usually cannot cause increasing or decreasing population densities.

In my work, erroneous interpretations of the effect of one variable on fish population density could have involved gradients, elevations, and pool-riffle ratios. As channel gradients increased from two to four percent, population densities increased; above four percent they decreased. Although gradients do affect fish population densities it is correlated with stream depths and size ratings, which also influence fish population densities. Fish population densities were highest in channels having 30 to 50 percent pool ratings rather than the often stated 50 percent optimum. The deeper and wider streams were in the lower elevations and naturally had relatively low pool-riffle ratios, yet these streams had the higher fish population densities. Nevertheless, if these streams had had higher pool-riffle ratios, they might have had still higher fish population densities.

Although many authors have demonstrated that increasing fine sediments under temporal conditions are detrimental to aquatic life, this was not the case in this study when I compared spatial conditions. If I had considered fine sediments by themselves as

a dominant controlling variable, the conclusion would have to have been that increasing amounts of fine sediment in the channel would cause increased fish production. In analyzing the combination of variables, however, as fine sediments increased in the study streams, stream widths and depths, pool quality ratings and percent pool evaluations increased, while channel gradients decreased. All of these are variables that cause an increase in fish population densities. In analyzing any aquatic environment, all environmental variables and their interactions must be considered.

Chemical Conditions

Hydrochemistry

Because of the homogeneous granitic material, water quality throughout the drainage was uniform and offered no bias in comparing fishery findings with environmental conditions.

The waters of the selected streams (Figure 16) were low in additives and were exceptionally "pure" in comparison to many Idaho streams (Appendix E, Table 33). Ratings of total solids, pH, total dissolved solids, alkalinity, hardness, calcium, magnesium, and silicon increased as flows decreased (Appendix E, Table 34 and Figure 17). The flows of streams in the study area naturally decrease during the period of sampling. No trends developed with the other chemical tests in comparison with time or flow. No geologic process group seemed to differ from any other group in following a rate of increase or decrease in dissolved or suspended solids with time or changing stream flow.

Spatial differences occurred in the amounts of dissolved and

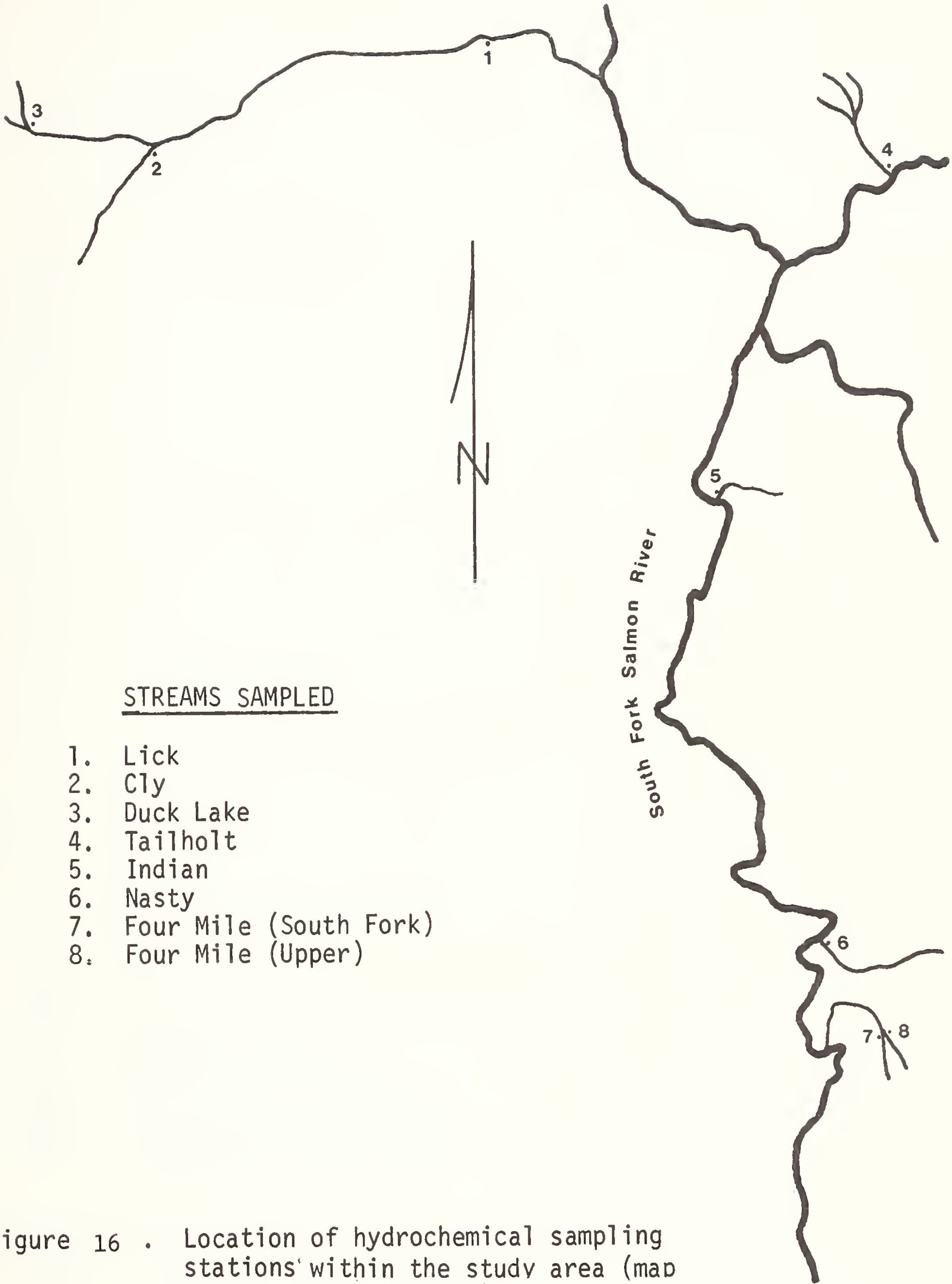

Figure 16 . Location of hydrochemical sampling stations within the study area (map scale - 3/8" = 1 mile).

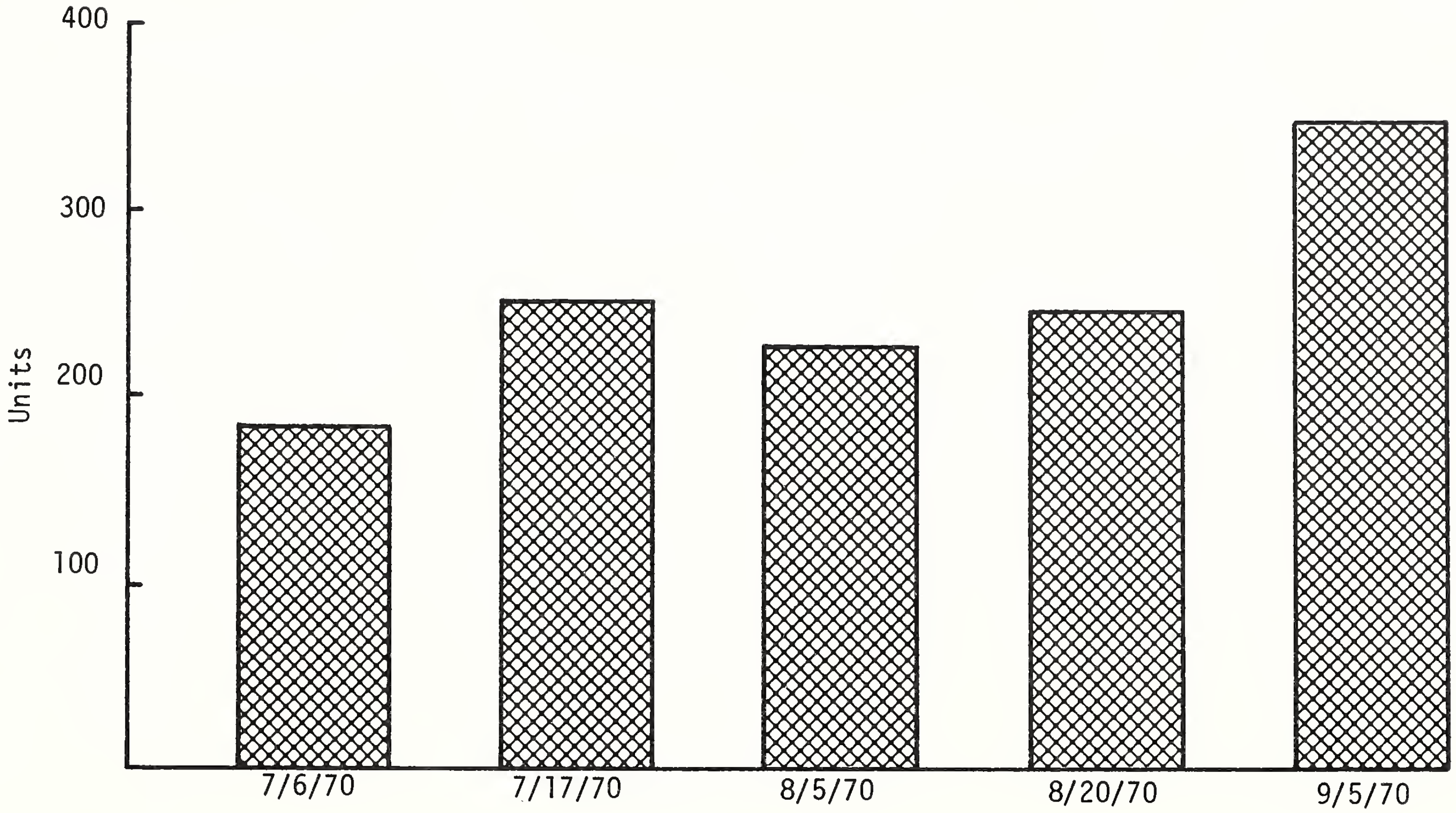

Figure 17. The mean temporal relationship of water additives by combined units from eight hydrochemical sampling stations within the study area.

suspended additives in the waters of streams of different geologic process groups. These differences appeared to be related to the degree of decomposition of bedrock and elevation of stream channels (Appendix E, Table 35 and Figure 18). Cly and Duck Lake Creeks, with the highest elevations and the least bedrock decomposition, had the "purest" water. Their total average ratings were 189 units, with units representing the total of the parameters measured. Lick and Four Mile Creeks, which flowed through depositional lands of the valley-train geomorphic type, were the next highest in water additives with an area rating of 240 units. This group, with its lower elevation lands, may have lacked a higher amount of additives in the water because their watersheds incorporated few or no fluvial lands, and their tributaries were mainly in the strongly glaciated lands which had undergone little decomposition of bedrock.

The strongly dissected mountain slope lands, with their steeper slopes and more highly decomposed bedrock, rated higher (314 units) than the moderately dissected mountain slope lands (259 units). This is explained by the parent materials of the strongly dissected lands being more decomposed and lower in elevation. Tributary streams in the fluvial geologic process group have commonly added more fertile waters into the South Fork of the Salmon River than the river contains. No streams in the cryoplanated lands were sampled because these lands naturally contain so few streams.

Spatial differences occurred in the quantities of dissolved and suspended additives in the waters of various geologic process groups. However, based on the difficulty other authors

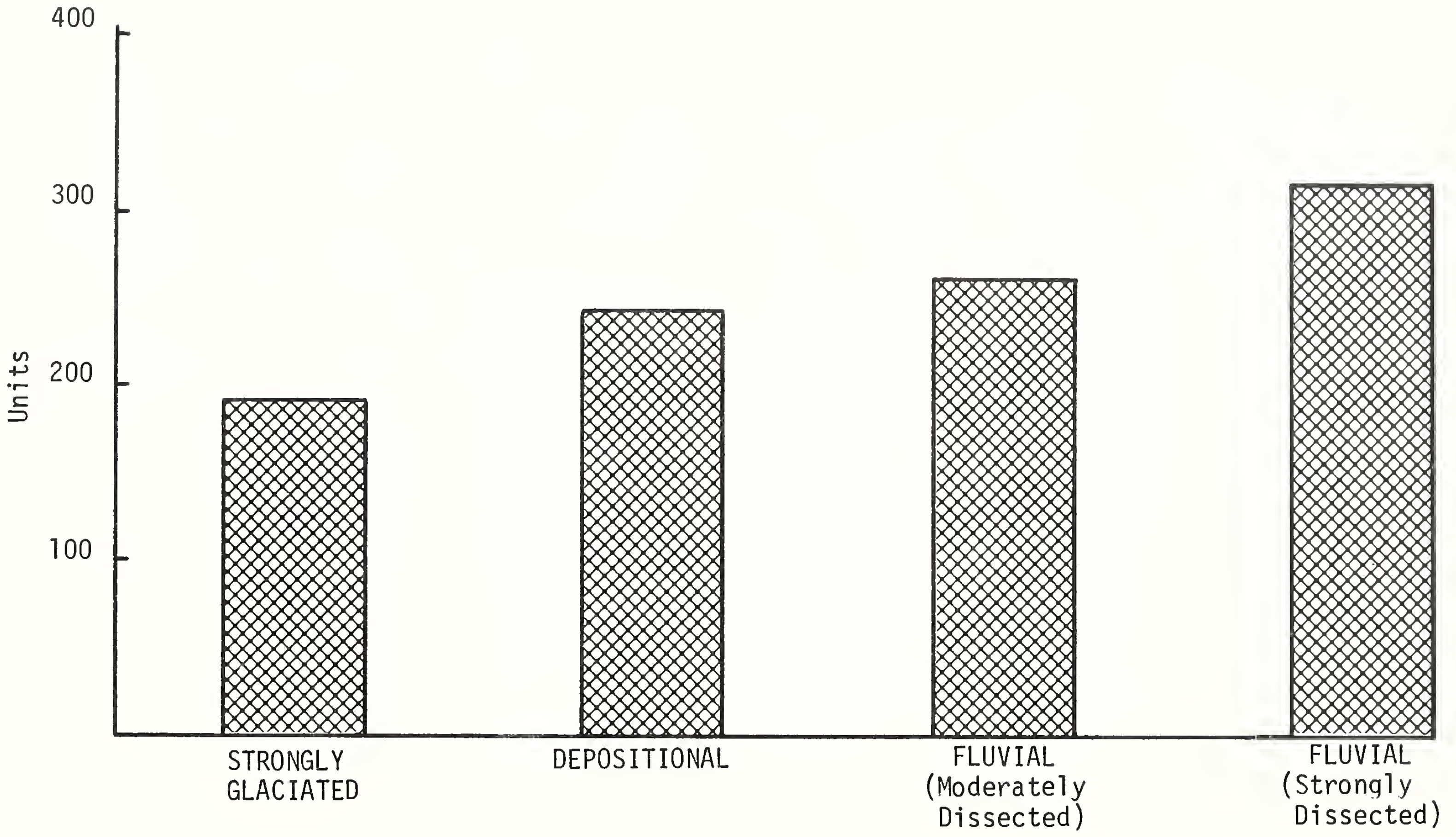

Figure 18 . The spatial relationship of geologic process group to additives of water by combined units from eight hydrochemical stations within the study area.

have had in attempting to correlate even much higher quantitative differences to biotic response, I concluded that our profiles of water quality among geologic process groups and geomorphic types were so closely related that they would not bias my environmental comparisons. Fish composition, fish size, and numbers of fish species were not correlated with amounts of additives in the waters of streams selected for hydrochemical profile determinations (Appendix E, Table 36).

STREAM ENVIRONMENTS IN DISTURBED AND UNDISTURBED WATERSHEDS

No major soil disturbance had occurred in the study area for at least five years prior to the initiation of this study. Some watersheds that had been disturbed as long as 15 to 20 years ago had had time to regain natural conditions (Appendix F, Table 37). It had previously been demonstrated at the South Fork of the Salmon River that when large streams were stressed from disturbed granitic watersheds, they could return to nearly natural conditions in 15 to 20 years after the stress from the stress from the surroundings was relieved (Platts 1972).

A comparison of the mean stream variables (Appendix F, Table 38) and the multivariate analysis information indicated that if the structure of the stream in disturbed watersheds was changed because of roads and logging, the streams recovered very fast. Most of the outstanding aquatic structural differences can be explained. Gradients were higher in undisturbed areas since they included the cryoplanated and strongly glaciated lands, where streams naturally have high gradients.

Disturbed streams were wider and deeper, but because logging areas were mainly in the lower part of the stream systems--in fluvial lands-- this would be expected. Undisturbed streams have a higher pool-riffle ratio, but this would be expected as the cryoplanated and strongly glaciated lands have the highest pool-riffle ratios. Pool and streambank conditions ratings were almost identical, and channel elevation averaged 407 feet higher in the undisturbed areas.

Composition of materials of stream channels differed from four to six percent. Fine sediment and boulder ratings in undisturbed and disturbed watersheds were higher in undisturbed high-elevation streams. I have no explanation as to why fine sediments were not less in these streams as would have been expected.

Fish populations were much higher in disturbed streams, but again much of the logging activity influenced the larger streams at lower elevations (Appendix F, Table 39). Cutthroat trout were found only in undisturbed streams or stream segments which occupied mainly higher elevation areas.

About the only interpretation that can be made from my data (including the multivariate analysis) is that if tributary streams were stressed by logging disturbances, they had returned to conditions that are either natural or undetectable. Logically, tributaries having higher gradients would be expected to recover from accelerated fine sediment stress at a faster pace than the river.

The computer program for analyzing streams in disturbed and undisturbed watersheds was not set up to eliminate the biases. The program should have attempted to compare undisturbed to disturbed conditions by geomorphic type, elevation, and channel gradient. This would have eliminated the bias of logging centered in areas containing wider, deeper, and more productive streams.

GEOMORPHIC PROCESSES AND STREAM ENVIRONMENTS

The geomorphic processes of glaciation and fluvial erosion have created recognizable systems of landforms in the study area, representative of those in the contiguous areas within the Idaho Batholith (Figures 19 through 26). Soil scientists have classified, mapped, and demonstrated that landform differences correlate with soil, geologic, and vegetative differences. Howard and Spock (1940) define a landform as "any element of the landscape characterized by a distinctive surface expression or internal structure, or both, and sufficiently conspicuous to be included in a physiographic description." Results of this study revealed that landforms correlate with certain types of stream environments.

The relationships between geomorphic processes, specific landforms, and specific aquatic environments were proved, of course, only for the study area. It will take further studies to determine if these relationships occur in areas having other lithology, parent materials, and climatic conditions.

Aquatic Classification

Geomorphic Process Group

The study area had been morphogenetically categorized according to dominant geomorphic processes into four main groups by Arnold and Lundeen (1968). Results of my work demonstrated that each of their geologic process groups contained different aquatic environments. The aquatic environment differences were sufficient to permit complete stratification at the group level.

Figure 19. A typical type of the high-elevation valley train (104), area characterized by constant low flows, very stable banks and channels, and by low and rocky streambanks.

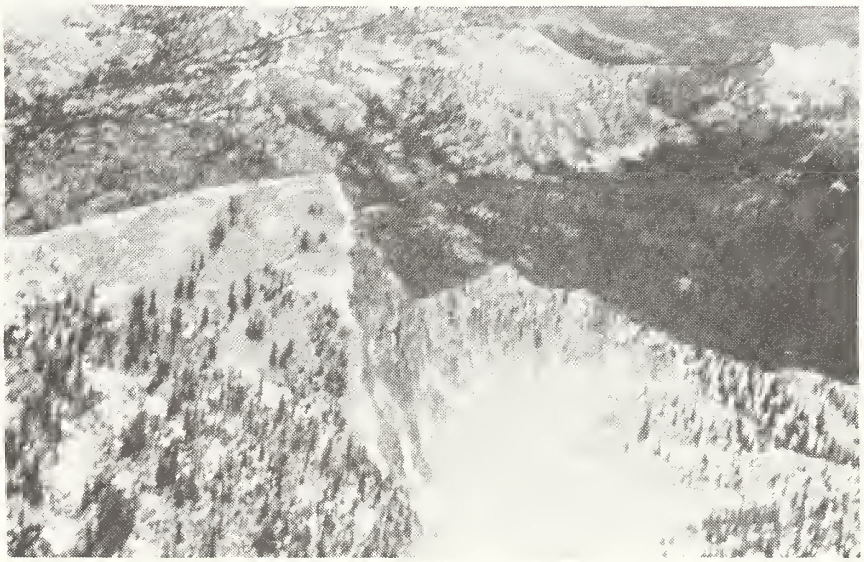

Figure 20. Strongly glaciated lands including a cirque basin (110) that contains a small lake. The granitic bedrock is hard, unweathered, nonspalling and slightly to moderately fractured. The depressionaly nature of the landscape allows for deep percolation and the conversion of precipitation to subsurface flow, which acts as a chief regulator for streamflow from the headwaters.

Figure 21. The Rice Creek drainage with a valley train (104) area along the bottom and lower side slopes of the U-shaped glacial trough. The valley train (104) lands effectively buffer the stream from surrounding steep glacial trough lands (111), and little surface water enters the stream. Note clearcuts on south slopes.

Figure 22. Strongly dissected mountain slope lands (120c), with slopes between 55 to 70 percent and drainage ways usually spaced less than 500 feet apart. These areas are subject to the most severe sediment hazards from logging and road construction and they naturally introduce high amounts of sediment to streams.

Figure 23. Moderately dissected mountain slope land (120b) in Lodgepole Creek with slope gradients of 45 to 60 percent. Drainages are generally spaced 500 to 1,500 feet apart, and these fluvial lands are usually found in the 3,500 to 6.000 foot elevation range. Logging activity on such lands can seriously damage streams unless road density is minimal.

Figure 24. Dissected fluvial lands with logging clearcuts on faulted bench land (123). This entire valley floor is depositional land composed mainly of the moraine geomorphic type (106).

Figure 25. An end moraine geomorphic type (106) bordering Warm Lake with Six Bit and Dollar Creeks in the background. Clearcuts occurred in the Cabin Creek area. The surrounding mountainous areas are mainly fluvial character.

Figure 26. Cryoplanated lands (109) in the study area occurred near strongly glaciated lands. The cryoplanated lands are poor acquifers and provide little surface water for sustained streamflow. The more gently sloping areas are favorable for roads because sediment rates are low.

Stream channel gradients in the strongly glaciated lands (Appendix G, Table 40) greatly exceed that of channels in the other geologic process groups. Because mountain slope lands (fluvial geologic process group), cryoplanated lands, and valley train lands (depositional group) all have steep topography, channel gradients in all these lands are about equal.

Strongly glaciated and cryoplanated lands had much smaller streams than occurred in fluvial or depositional lands. Because streams in the glaciated lands had lower width-depth ratio, however, stream depths were almost identical among all geologic process groups. Streams in strongly glaciated and cryoplanated lands had the highest pool-riffle ratio ratings which agreed with their lower width-depth ratios. Streams in depositional lands had equal amounts of pool and riffle areas; streams in the fluvial lands were dominated by riffle areas.

Streambanks in the fluvial lands were largely controlled by the valley side slopes, which limited the capability of the stream to build bank pools. Streams in depositional and strongly glaciated lands had more direct influence on their own banks. The high erosion rates, sediment types, and amounts of overland water flow per unit area in the cryoplanated lands controlled streambank conditions.

Strongly glaciated stream channels were dominated by substrates of boulders and gravel while cryoplanated lands were dominated by rubble and fine sediment. The differences were probably due to the differential effects of snow, ice, and cold temperatures. Stream channels in fluvial lands were dominated

by boulders and rubble (Figure 27). Substrates streams in depositional lands were well-balanced in composition (Figure 28).

The depositional geologic process groups could be separated into two groups based on whether ice or water dominated material deposition. The aquatic types within such groups could then be stratified (Appendix B, Tables 6 and 7).

Geomorphic type

Geomorphic types imply certain soil and water management hazards and are the basic unit of land classification. Aquatic types should serve the same purpose for aquatic classification.

The geomorphic types within the study area had previously been stratified according to stage, four process groups, and 20 geomorphic types (Appendix G, Table 42). I compared the aquatic ecosystems with this stratification by using quantified variables of stream structure, fish numbers, and fish species composition (Appendix G, Table 41).

Because streams were few or entirely lacking in some geomorphic types, only eight of the potential 20 geomorphic types within the study area permitted adequate samples (Appendix G, Table 43).

In comparing stream environments with geomorphic types, I encountered difficulties with streams in geomorphic types that are in the same geologic process group. In comparing aquatic environments among geomorphic types in different geologic process groups, however, structural aquatic differences allowed satisfactory stratification. Stream environments in the different geomorphic

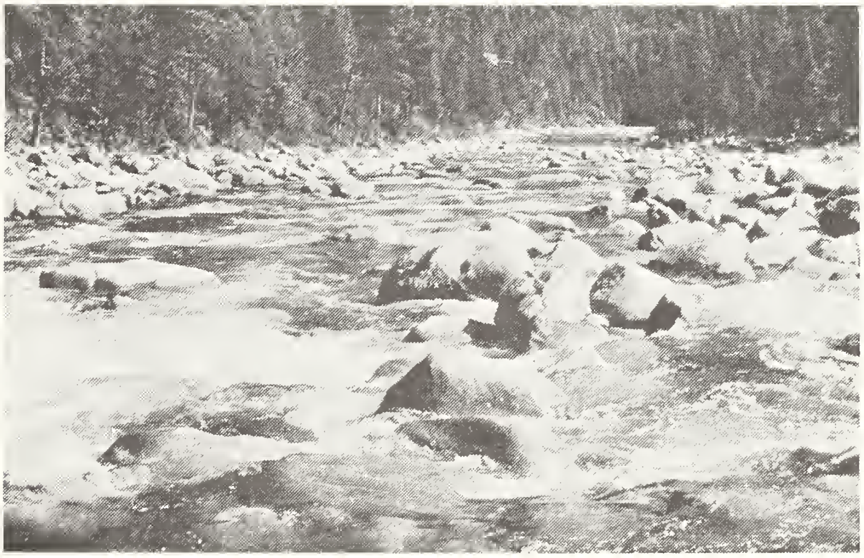

Figure 27. Example of a stream dominated by boulders in the oversteepened canyon lands (122) downstream from the study area. The channel in these lands contains larger particles than were found in most of the other geomorphic types.

Figure 28. An aquatic type in the depositional geologic process group within the alluvial lands (101) influenced by updrainage disturbed lands. These streambanks have good cover and stability, but the sediment transport rate is high, and gravel and rubble particles tend to be cemented together with fine sediment.

types that constitute depositional lands were quite similar except when they ran through glacially deposited materials vs. through water deposited materials. Classification of aquatic environments by geologic process groups thus required dividing the depositional lands into two groups -- one composed of materails laid down or worked by water and the other of materials laid down or modified by ice.

The following 11 geomorphic types account for 26 percent of the study area and did not contain streams, or only small and insignificant streams:

River Terrace	(102)
Toe slope	(107)
Glacial plastered mountain slope	(108)
Cryoplanated geologic process group	(109)
River Spur	(112)
Rocky ridge	(113)
Subalpine rim	(114)
Glacial scoured mountain slope	(115)
Faulted glacial scoured uplands	(116)
Oversteepened canyon	(122)
Faulted bench	(123)

The river spur and oversteepened canyon geomorphic types, however, become high producers of sediment to down-drainage streams. Roads across these 11 types of land will seldom intercept major perennial streams; and although culverts should be

required for passage over surface water, bridges would seldom be a requirement.

The remainder of the study area's geomorphic types (74 percent of the area) contained streams, with the majority running through alluvial, valley-train, and dissected-mountain-slope lands. These are the very sensitive lands that need intensive management to insure land uses that are compatible with the needs of the streams.

Many streams in different geomorphic types showed differences that could be related to process, but some aquatic variables could not be thus related. The geomorphic types made up of depositional materials, except for valley train lands, had low gradients; alluvial fan lands had the lowest gradients. The valley train lands were ice-formed which accounts for their steeper stream gradients.

Terrace and oversteepened canyon lands naturally are along the larger water courses so one would expect streams intercepting these lands to be larger. Stream widths and depths followed geologic process group but not geomorphic type stratifications. Cryoplanated lands seldom support streams and those that occur are small. Complete stratification could not be developed between all geomorphic types using pool-riffle ratios because most streams in depositional materials had similar pool-riffle ratios. Streams in strongly glaciated and cryoplanated lands have a higher pool-riffle ratio than dissected mountain slope lands.

Stream channel materials could be stratified better by geologic process group than by geomorphic type, except that valley

train lands differed from other geomorphic types composed of depositional materials, again due to the glacial influence. Percent of boulder ratings were higher and fine sediment ratings lower in streams of strongly glaciated geomorphic types than in cryoplanated lands where ice and snow action had been more stationary.

Streams in morainal lands contained the highest percentage of rubble because of the nature of till, which constitutes moraines. Cirque basin lands had the lowest percent rubble ratings but the highest percent gravel ratings compared to all geomorphic types. Glaciation and nivation would probably be the largest factors in creating rubble and gravel for these streams. Channels in geomorphic types that produce abundant sediment (cryoplanated, dissected slope, and structural basin) and contain channels having low gradients (glacial outwash and alluvial fan) had more fine sediment than gravel.

Because streambank environments are mainly influenced by vegetation and my inventory procedure did not properly evaluate such environments, I could not adequately compare bank environment between geomorphic types. Streambanks are usually rated good to excellent throughout the study area; streambank variable differences were small between different geomorphic types.

Our results did not allow complete aquatic environment stratification to the level of the geomorphic type. This could have been due to the inadequate study methods used, or the geomorphic type land stratification could have been inadequate. Both systems were faulty, and the land stratification to the geomorphic type levels needs further refinement. However, most of the aquatic

environments within geomorphic types can be described and stratified in correlation with the land system's stratification (Appendix B, Table 7).

DISCUSSION

Geologists and soil scientists have demonstrated that each geomorphic process developes its own characteristic assembalge of landforms. The main objective of this study was to determine if such land classifications could be used to describe or classify aquatic environments in mountainous granitic lands.

Streams in the Idaho study area did prove to have characteristic distinguishing features that were influenced by geomorphic processes. In other words, these streams, which drained lands formed by similar processes, displayed a degree of uniformity. Results of the Idaho study thus supported the hypothesis that can be classified over large areas if each such environment has been associated with a specified landform. This hypothesis should now be tested in other kinds of terrestrail environments. The just completed work should permit aquatic environments within the Idaho Batholith (granitic lands) to be classified to the level of the geologic process group, with most of the aquatic environments being extendable to the level of the geomorphic type.

Comprehensive land use planning and management of ecosystems in granitic lands requires that the aquatic environments be described, stratified and meshed with the stratification of landforms. If land and water managers are to fulfill their responsibilities as stewards of the lands, they first must know the type and condition of the lands and waters they manage. They must

know how each land management unit and its aquatic types will react to certain land or water uses before they can adequately evaluate potentials for degradation and ways to mitigate such potentials.

This study provided a basis or framework for similar studies involving other geologic and lithologic settings. In this way aquatic environments will become identifiable units which can be integrated, through a methodology similar to ECOCLASS, into all land management programs. Probable responses of each land unit and its associated aquatic environment could then be considered in predictions of how environments will react to various land and/or water uses.

Past detailed research has established the physical, chemical, and biotic characteristics of diverse aquatic environments. Other detailed investigations have defined the geologic and morphological features of various watersheds. By combining the results of these additional findings, as this study has done, relationships between the geologic, hydrologic, and biotic characters can be determined and comprehensive ecosystem management can be achieved.

Results of this study demonstrated that aquatic systems may be dominated by one type of external variable such as glaciation, but multivariate control mainly determines stream conditions. The influence of glaciation, although it occurred 10,000 to 20,000 years ago, can still be seen in channel gradients and in elevations, quantities of water additives, pool-riffle ratios, and materials in

the stream channel. In depositional lands, whether the deposited materials were laid down by ice or water, significantly influenced what type of aquatic environment was formed. The degree of decomposition of bedrock was an important part in determining water fertility.

Physical stream characteristics such as mean depth, width, elevation, quality of pool, percent of pool, and streambottom materials directly affected the quantity and quality of fish numbers and species in a stream. Mean stream depth and width, along with channel elevation were the most important variables affecting fish population densities, fish distribution, and fish species composition.

The relation of the structure of the stream to changing physical variable of the stream followed the findings of other authors. Some changing spatial conditions such as increases in mean stream widths and depths, were associated with decreases in other variables of the stream such as channel gradients and elevations, percent of riffle ratings, percent of gravel ratings, and streambank quality evaluations. These relationships can now be predicted for comparable streams. However, expected relationships between stream elevations and gradients were not identified. The flat gradients of the highland streams precluded uniform conditions. The combined environmental conditions determined the quality of the aquatic environments, with individual aquatic variables tending to be influenced by other variables.

Results of this study further documented that the status of fluvial trout populations is determined mainly by the quality of the

aquatic environment. Salmonids are apparently adapted to most of the streams in these high elevation granitic lands. Some species were adapted only to certain ranges of stream gradient, and certain species usually peaked in population density at different channel gradients. Some fish species occupied certain types of environments because they were limited in competitive ability. This is exemplified by cutthroat trout and Dolly Varden, which occupied sections of streams that did not have high populations of chinook salmon and rainbow trout.

In the Idaho area, the main fishery resource was located in very few geomorphic types with most of the geomorphic types not being capable of sustaining a fishery. This would allow the land manager to concentrate on definable areas of land in need of intensive management. The study results also help pinpoint environments utilized by rare and unique species.

In evaluating the inventory procedure as a predictor of fishery conditions, flaws became apparent. Our multivariate analysis demonstrated that while multiple data were gathered, completely reliable information was lacking. A valid inventory needs to be developed that will satisfactorily describe various ecosystems. Available methods failed to describe adequately pool quality and streambank environment, and aquatic vegetation. Present methods could be revised for application to smaller streams (30 feet in width). Relationships between streambank environments and aquatic vegetations and fishery values were poorly defined using available methods. This area needs intensive research because it relates directly to the maniuplation of vegetation by

land and water managing agencies. Results of the Idaho study did demonstrate that, with adequate sampling (200 samples or over), the methods used to determine mean depth, mean width, composition of stream channel substrate, percent of pool, percent of riffle, and channel elevation were reliable, and confidence intervals at the 95 percent confidence level were acceptable.

Results of the Idaho work indicated that small, high-gradient streams, when stressed by bedload sediment can (as has the south fork of the Salmon River) return to natural or near natural conditions in a short period of time once the stress is removed. In the area in question, the period that has elapsed since land disturbance, has been long enough and channel competencies and rates of watershed healing high enough that almost all disturbed tributaries have probably reverted to their natural or near-natural conditions.

CONCLUSIONS

Stream Characteristics

1. Aquatic environments can be described, classified, and worked into ecosystem classification methodology at the geologic process group level and with some success to the geomorphic type level in the south fork of the Salmon River drainage. Results of this study should allow the indicated aquatic descriptions and classifications to be applied throughout granitic lands of the Idaho Batholith that have undergone the same processes by utilizing land classification maps based on geomorphic processes. This conclusion is based on the uniformity that was observed among streams draining lands that had been formed by similar processes.
2. Aquatic environments within the area's depositional geologic process group were further classified into two subgroups:
   1. Depositional materials worked and deposited by water.
   2. Depositional materials deposited or modified by ice.
3. Geomorphic types (which make up 26 percent of the study area) contain only few small and insignificant streams.
4. The majority of the streams in the study area fell within three geomorphic types: alluvial, valley train, and dissected mountain slope.
5. Streams in strongly glaciated lands had the highest elevations.
6. Only low amounts of suspended and dissolved solids were recorded, with no indication found that water additives in different

geologic process groups followed different temporal (comparing temporal rates of change between groups only) rates of increase or decrease with changes in stream flows. Spatial differences in water quality between geologic process groups appeared to be related to degree of decomposition of bedrock and channel elevation. Such differences, however, based on past research are considered insignificant in influencing environmental comparisons.

7. As streambank quality increased in the study streams, ratings of stream depth, percent of riffle, percent of fine sediment, and pool quality decreased; while those of channel gradient, percent of pool, and percent of boulder increased.

8. As stream channel gradients increased in the study streams, channel elevations and streambank stability ratings increased; while stream depths, widths, and percent of gravel ratings decreased. Pool area dominated channels having zero to two percent gradients, but above three percent, riffle areas were dominant.

9. Stream channels having gradients of three percent or less had their substrates dominated by fine sediments and above three percent boulders were dominant.

10. As channel elevation increased in the study streams, percent of pool and percent of gravel ratings increased; while stream widths and depths and percent of rubble ratings decreased.

11. As stream channel widths increased in the study streams, channel gradients and elevations, along with percent of gravel and streambank condition and type ratings decreased; concommitantly, stream depths and percent of boulder and

percent of stream in riffle ratings increased.

12. As stream depths increased in the study streams, decreases were noted in channel gradients and elevations, along with percent of riffle, percent of gravel, percent of rubble, and streambank environmental quality ratings; by contrast, stream widths, percent of stream in pool ratings, quality of pool evaluations, and percent of fine sediment values increased.

13. As the percentage of fine sediment increased, the quality ratings given the pools became better; as the percentage of boulder increased, the quality ratings given the pools decreased.

14. Streamside environments were rated as very good throughout the study area.

15. The methods used to quantify the aquatic environmental conditions failed to describe adequately pool quality, streambank environment, and aquatic vegetation. Where sample size was sufficient, the methods used were reliable for quantifying and making comparisons among mean stream depths, and widths, composition of stream channel materials, percent of pool and percent of riffle ratings, and channel elevations. The inventory techniques demonstrated that even though considerable data may be collected, valid information is elusive.

Fish Characteristics

1. The cryoplanated lands contained few streams, and no fish were found in these streams.

2. The highest fish population densities were recorded in

channels having 30 to 50 percent of the stream classed as pool areas.

3. Only 8 of the 26 geomorphic types and 3 of the 4 geologic process groups had streams that supported fluvial fish populations.
4. Streams in depositional lands (which only make up 10 percent of the area) contained most of the fish populations.
5. The majority of the fish populations occurred in streams of the valley train and dissected mountain geomorphic types; the west slope cutthroat trout occupied only these two types.
6. Salmonids are apparently adapted to almost all tributary streams in the study area. Streams draining multiple geomorphic types had higher fish standing crops and more fish species than did streams draining single types.
7. The productivity and composition of fluvial trout populations were determined mainly by the structure of the aquatic environment.
8. Areas of the stream channels that supported the highest fish densities also had the highest number of fish species present.
9. Areas of channels with high populations of rainbow trout had low Dolly Varden populations. Sculpin were found only in combination with rainbow trout.
10. As channel gradient increased, numbers of fish species decreased; no fish were found in channels having gradients above 25 percent.
11. The lower the average channel elevation, the higher was the density of the fish population.
12. Fast water pools were most attractive for rainbow trout.

13. As stream widths and depths increased, the total density of the fish population per length of stream increased.

14. Fish population densities were highest in channels having streamside cover dominated by a grass-brush habitat type; chinook salmon favored grass types while rainbow trout favored brush types.

15. As the percent of fine sediment in the channel increased, fish population densities did not decrease; no other definite relationships were noted between fish densities and other classifications of channel substrate.

16. Pools classified as being of excellent quality had the highest population densities because of their chinook salmon. Rainbow trout and cutthroat trout populations were inversely related to increasing pool quality.

RECOMMENDATIONS

1. The inventory method that was used in this study to achieve aquatic environment descriptions and to quantify variables needs further refinement.
2. The methodology and framework developed in this study to classify and describe aquatic environments within the south fork of the Salmon River drainage, should be applied elsewhere to test the hypothesis that like landforms and like associations of landforms are a chief determinant of uniform aquatic environments.
3. Aquatic classifications (as developed in this study) should be included in any land and water stratifications designed to promote total ecosystem classifications. The overall results should then be carried through the steps of land use planning to the decision making stage at the comprehensive resource use and activity planning levels.
4. Aquatic systems should be inventoried and classified relative to all terrestrial systems. The resultant ecosystem information could then be applied systematically to the decision making process at any level.

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APPENDIXES

APPENDIX A:

List of fish species present in the study area.

Table 5. List of fish species present in the study area with population abundance rating.

Common Name	Scientific Name	Population Rating		
		Abundant	Common	Low
Cutthroat trout	Salmo clarki Richardson		x	
Dolly Varden	Salvelinus malma (Walbaum)		x	
Rainbow trout	Salmo gairdneri Richardson	x		
Mountain whitefish	Prosopium williamsoni (Girard)		x	
Chinook salmon (summer chinook)	Oncorhynchus tschawytscha (Walbaum)		x	
Steelhead trout	Salmo gairdneri Richardson		x	
Brook trout	Salvelinus fontinalis (Mitchell)			x
Northern squawfish	Ptychocheilus oregonensis (Richardson)			E
Suckers	Catostomus spp			E
Redside shiner	Richardsonius balteatus (Richardson)			E
Dace	Rhinichthys spp			x
Sculpin	Cottus spp			x
Pacific lamprey	Entosphenus tridentata (Gairdner)			E

E = Estimate only.

APPENDIX B:

Description of geomorphic and aquatic environment conditions by geologic process group and geomorphic type.

Table 6. Description of geologic process groups and their aquatic environments within the study area.

Strongly Glaciated Process Group

Geomorphic

Strongly glaciated lands are found above 6,000 feet in elevation and occur mainly in the headwaters of the South Fork Salmon River and its tributaries. They include 96,830 acres and make up 38 percent of the study area. These lands have been shaped by scouring and wearing down by alpine glaciation and are characterized by straight U-shaped glacial valleys that generally have a parallel drainage system. Landforms associated with strongly glaciated lands are cirque basins, headwalls, rocky ridges, and weakly expressed horns.

Aquatic Environment

Streams in the strongly glaciated geologic process group average much smaller than those in fluvial or depositional lands. They are dominated by pools of poor quality, have high pool-riffle ratios, low width-dept ratios. Channels are dominated by boulders and gravel with low amounts of fine sediment and rubble. These channels contain more boulders and gravel by percent and less rubble and fine sediment than do channels of any of the other geomorphic process groups. Channel elevations are the highest of those examined causing streams to be exposed to extreme conditions of winter icing and they have colder water temperatures during the summer. Streams in this group lie in U-shaped valleys with wide buffer zones between them and the valley slopes. This results in very little overland water flow carrying sediment into the streams. Channel gradients are steeper than those of channels in the other groups because of hanging valleys and the gradient of horizontal stairsteps of the valley. Streambanks are very stable with high amounts of boulders. Streamside cover is dominated by trees and brush. Water additives are very low in amount resulting in quite pure, infertile water. There is less fluctuation between maximum and minimum flows than occurs in any of the other geologic process groups. Streams of this group are much shallower than those in the fluvial and depositional lands.

Fish population density and the number of fish species present are extremely low. Glacial trough lands contain the bulk of the existing population. Rainbow trout are the dominant species, but anadromous rainbow probably do not occupy the area. Cutthroat

trout and Dolly Varden may inhabit streams of this geologic process group, but populations would be extremely low.

Cryoplanated Process Group

Geomorphic

Cryoplanated lands form a complex or transition zone below or adjacent to the strongly glaciated lands and include 17,180 acres (seven percent of the study area). In these lands the effects of ice and permanent snowfield action are mainly localized. The soil and rock materials were not carried by major ice currents as in the case of the strongly glaciated lands with their U-shaped valleys. As a result, the lands have subdued topography. The slopes are more gentle and mostly convex in shape. In most cases, the cryoplanated lands have weakly expressed drainage development. This is partially due to the dominant slope forming processes that are presently active in these slopes. Cryoplanated landscapes are at elevations where nivation, freezing, thawing, wetting, solifluction, and drying make mass wasting the chief process by which materials are moved downslope. These processes keep replacing materials that may have been removed by overland flow.

Aquatic Environment

Streams are scarce in cryoplanated lands and those that do occur are mainly first-and second-order and are poorly developed. They are small and narrow, but have the lowest width-depth ratio of all streams in the study area. These streams are about equal in size to those in the strongly glaciated lands but much smaller than streams in the fluvial or depositional lands. Because of the constant subsurface frost churning and soil movement, streams may be nonexistent over large areas or occur thousands of feet apart. Channel gradients are steep and channel elevations high but less so than in strongly glaciated lands. The average area of stream in riffle is low, with poor quality of pools dominating stream characteristics. Average quality of pools rated higher than other geologic process groups which could be due to the lower ratio of width to depth. However, there may not be a statistical significant difference. Because of their predominantly south aspect, stream temperatures are higher than those in strongly glaciated lands. High erosion rates from the slopes mean that channels are dominated by fine sediments, with the percent of fine sediments higher and percent of boulders lower than in any other geologic process group. Percent of rubble is higher and gravel lower than in streams in the strongly glaciated lands. Streambank cover is dominated by trees, but stability of the bank is only rated good because of the high surrounding rates of erosion and types of mass wasting processes. Streams are only slightly

Table 6. (Continued)

entrenched and lie in shallow valleys that are between U- and V-shaped. The limited extent of any surrounding buffer zone permits direct overland flow and eroded soils to enter the streams.

Fish populations usually are nonexistent. And, if fish are present, their density and number of species are extremely low. It is doubtful if anadromous species ever use this area.

Fluvial Process Group

Geomorphic

The fluvial lands are located along the lower slopes. They include 114,260 acres (45 percent of the study area). Stream-cut lands provide 80 percent of the naturally occurring sediment production. Seventy eight percent of the logging and 69 percent of the road construction have been on fluvial lands (Arnold and Lundeen, 1968). These lands usually occur below the 6,000-foot elevation; are characterized by steep, V-shaped valleys; and have a strongly expressed drainage system. The dominant geomorphic process active on most of these lands is the erosive force of running water. The process of fluvial action by streamcutting, however, is not the only active process in this broad geomorphic group. Mass wasting, uplift, faulting, and structural control have also contributed to the shape of these lands.

Aquatic Environment

Streams in the fluvial geologic process group have fairly high gradients with a high width-depth ratio, as evidenced by riffles dominating the stream. Percent of pool is lower and percent of riffle is higher than in streams of any other geologic process group. Although the streams are wide, they tend to be shallow with poor quality pools. Channel materials are dominated by boulders and rubble, and the fine sediments exceed gravel, which reflects the high rate of soil erosion from the slopes. Stream-side cover is dominated by trees and brush; bank stability is rated only good. Streams lie in V-shaped valleys that have steep side slopes. Very little buffer (floodplain) lies between the stream and valley sides. This results in direct input of surface waters and sediment during snowmelt and storms. These streams have the lowest elevation of all channels considered, and, because of well-weathered bedrock, their water additives are higher than in streams of any other geologic process group. Therefore, these waters, with their higher water temperatures are more fertile than those in other geologic process groups.

Rainbow trout are the dominant fish species, followed by chinook

salmon, Dolly Varden, cutthroat trout, brook trout and sculpin. Fish numbers average about one per 10 feet of stream. The west-slope cutthroat trout occupy this area, but they occur at only about 50 percent of the population density of cutthroat trout in the valley train lands.

Depositional Process Group

Geomorphic

The depositional lands of alluvial or morainal origin in the drainage bottoms account for 25,930 acres (10 percent of the study area). These lands were formed by water and glacial deposits and occur throughout the study area in all of the geomorphic groups. Except in the Warm Lake Basin area, depositional lands are a small portion of the study area. When considering the aquatic environment, however, these lands are extremely important because they include: (1) both sides of streams in the U-shaped glacial trough, (2) terraces adjacent to streams, (3) the morainal, glacial outwash, and fluvial deposits, and (4) the glacial deposits that compose the valley train geomorphic type.

Aquatic Environment-Water Deposited

In this group, stream channels have low gradients, and the streams are the largest in the study area. Width-depth ratios are high. These streams build their own banks. Pool quality, however, is still poor, and riffles dominate the channels of the streams. Channel materials are very low in percent boulders and high in fine sediment, while gravel and rubble are abundant. The high amount of gravel provides the better salmonid spawning environments found in the area. A wide, flat floodplain between the stream and valley slopes acts as a buffer zone. This buffer restricts overland water flows and sediment from the sides of the valley from entering the streams. The streams, however, usually receive high rates of sediment from upstream fluvial lands. Streamside cover is dominated by trees and brush; stability of streambanks in good.

Streams in these lands contain the highest number of fish species, having all the species that were recorded in the study area. Chinook salmon rely more on streams in these lands for spawning and rearing than on streams in any other geologic process group. Chinook salmon is the dominant species followed by rainbow trout, brook trout, sculpin, Dolly Varden, mountain whitefish, and dace. Population density of cutthroat trout is very low. Sculpin populations density is higher in these streams than in streams of any of the other lands.

Table 6. (Continued)

Aquatic Environment (Ice Shaped or Deposited)

The main reason for separating the depositional lands into two groups was to isolate the streams in valley train lands which do not resemble the other depositional geomorphic streams. In doing this, the moraine land streams had to be included here even though they are intermediate between streams of water-deposited lands and composed of deposited materials gouged out of the valley train lands. The ice-shaped or-deposited stream description refers mainly to valley train lands.

Stream channel gradients are steep here, matching those of streams of the valley slope. Channel materials are low in gravel and fine sediments being dominated by boulders. Riffles dominate streams environments with a poor quality of pools. The valley trains land streams lie in wide, U-shaped valleys with wide buffer zones lying between the streams and side slopes. Overland surface water flows and direct sediment input entering the stream are low. Streamside cover is dominated by brush and trees.

Dace, mountain whitefish and sculpin are lacking, or populations are extremely low. Rainbow trout are the dominant species followed by Dolly Varden, cutthroat trout, brook trout, and chinook salmon. This is the main geologic process group used by the cutthroat trout; however, they average only one cutthroat trout per 250 feet of stream. Chinook salmon use the lower sections of the stream for spawning and rearing. Sculpin are lacking, which means these streams do not meet the environmental needs of other fish; sculpin are only found in the geomorphic types having relatively high densities of fish populations.

Table 7. Descriptions of geomorphic types and their aquatic environments within the study area. Numerical numbers in parenthesis represent the geomorphic map code.

Strongly Glaciated Geomorphic Process Group

Cirque Basin (110)

Geomorphic

Cirque basins consist of amphitheater-like basins, which were found at the heads of most of the glaciated valleys. Some of the cirque basins contained small lakes; the larger cirque basins usually had small areas of wet alluvial lands near the lakes. Common inclusions were narrow strips of valley train (104) and toe slope (107) lands.

Aquatic Environment

Stream channel gradient was close to channel gradients in valley train lands, which was surprising. This was probably due to the stairstep aspect of the stream channels with some sections having a very high gradient. These streams were the smallest ones studied and were very shallow. Channels were dominated by pool but had a pool-riffle ratio close to one with pool quality being very poor. Boulder dominated the stream channel with very little rubble and fine sediment present. Bedrock was hard and did not readily break down to bedload materials. For some unknown reason (possible nivation), gravel content were high in the stream channels. Streambank environments were nearly excellent. These were the highest elevation perennial channels in the study area. No fish were collected, and if populations did exist, they would be very low because of extreme winter conditions.

Glacial Plastered Mountain Slope (108)

Geomorphic

These modified slopes had glacial material deposited rather than stripped away by the scouring of the glacier. They were generally benched with fairly thick mantles of soil. Most of these lands were in the glacial troughs and contained considerable lateral moraine materials with typically rounded rock fragments.

Aquatic Environment

The steepness of these lands kept perennial streams in the lower valley. The lands did not contain fish populations.

Table 7. (Continued)

Glacial Scoured Mountain Slope (115)

Geomorphic

This type consisted of steep, benchy mountain shoulders which had been scoured by alpine glaciers. They generally occurred downstream from the cirque basin lands (110. and were between subalpine rim lands (114) and glacial trough lands (111). They were similar to the smooth and weakly dissected, glacial trough land. They did, however, have up to 30 percent rock outcrop, and, as a result of scouring, a thinner mantle.

Aquatic Environment

Because of the steepness of these slopes, they contained only a few perennial streams over four feet in average width. They did not contain fish.

Glacial Trough (111)

Geomorphic

Glacial trough lands occupied the side slopes of the glacial-formed U-shaped troughs typical of alpine glaciation. The preglaciation slopes had been oversteepened by the ice actions of glaciers. The stream drainage patterns on these lands were typically parallel, compared to the dendritic stream pattern in the fluvial lands.

Aquatic Environment

Because of the steepness of the glacial trough, its streams had the steepest channels of the streams studied. They were small streams, dominated by boulders. Fine sediments were almost non-existent because of the hard non-weathered bedrock, high channel elevations and high channel gradients. Streambank environments were almost excellent. Rainbow trout inhabited this geomorphic type but only at very light densities. Winter conditions were extreme, and this geomorphic type would not lend itself to significant production of fish.

Rocky Ridge (113)

Geomorphic

These types included the highest ridges, upper slopes, and extremely rocky spur ridges. They occurred mainly in the higher elevation glaciated lands. Talus slopes were common, and the

percentage of rock outcrop commonly exceeded 50 percent. Slopes were quite variable, often being 90 percent or more.

Aquatic Environment

The steepness and location of these lands included streams occurrence.

Subalpine Rim (114)

Geomorphic

This area consisted of subalpine mountain shoulders, mainly on south and west-facing slopes, which were not subjected to severe ice plucking and scouring and had not since been dissected by geologic stream actions. The slopes were relatively smooth, straight to weakly convex, and extended from ridgetops to as much as 1,000 feet in elevation downslopes. The adjacent landforms on north-and east-facing slopes were commonly rocky cirque headlands and cirque basin.

Aquatic Environment

The steepness and location of these lands included streams.

Faulted Glacial Scoured Uplands (116)

Geomorphic

This unit consisted of severely scoured glacial uplands that averaged 50 percent rock outcrop, which had been faulted since glaciation. The area was covered by huge faulted granitic rocks, some as high as 30 to 40 feet, with isolated pockets of soil between them.

Aquatic Environment

The steepness and location of these lands precluded all but a few streams.

Steep Rocky Cirque Headlands (112)

Geomorphic

These lands were the steep, rocky, ice-plucked cirque headlands of minor drainages, located above the cirque basin. Their granitic bedrock was hard, unweathered, nonspalling, and moderately fractured. The aspect was dominantly north; the elevation between 7,000 to 9,000 feet; and the slope gradient between 60 to 75 percent.

Table 7. (Continued)

Aquatic Environment

Because of the steepness and location of these lands, they did not contain streams.

Cryoplanated Process Group

Cryoplanated (109)

Geomorphic

Cryoplanated uplands were not subjected to the scouring action of the nearby strongly glaciated lands and were the result of the climatic changes brought about by glaciers. These lands were formed by the processes and effects of permanent snow and ice field action; any movement of materials was local. Generally, they were not dissected to any great degree by fluvial processes.

Aquatic Environment

Stream channel gradients were lower than in any of the glaciated lands. The streams had a difficult time forming in these lands because of the high rates of percolation and their position in the overall landscape. The few streams that did form were very small. The stream channels were dominated by pool, but the pool-riffle ratio was close to one. Boulders were lacking inthe channels, probably due to the weathered bedrock and unavailability of boulders. Fine sediments dominated stream channels as these lands are high producers of natural sediment. The cover on the streambanks was dominated by trees, but the high amount of incoming fine sediments lowered stability (condition) rates. Stream channels were of high elevation because they occurred in glaciated lands. Fish could not be found in the streams. If fish do exist, densities would be extremely low.

Fluvial Process Group

Faulted Bench (123)

Geomorphic

This special group of lands represented remnants of block (normal) faulting activity. The block faulting activity results in low, benchlike ridge systems which, in many cases, had been modified by glacial outwash deposits and moderately to weakly dissected. Faulted bench, structural basin, and river spur are not true fluvial types but are included under fluvial because, since their formation, they have been altered or formed by fluvial processes.

Aquatic Environment

These lands composed a very small portion of the study area and contained no streams of value to the fishery.

Dissected Mountain Slope (120)

Geomorphic

Dissected mountain slope lands consisted of slopes incised by stream drainages. The fluvial process was the dominate slope-forming influence. Streams were usually dendritic in pattern.

Aquatic Environment

The streams were in V-shaped valleys with steep side slopes and very little buffer from direct surface flows and sediment. Channel gradients were high but not as high as in the glaciated lands. Usually these streams received water from higher elevation geomorphic types so they tended to be larger than other geomorphic types in size. Riffles dominated the streams with pool quantity and quality being low. Because of the steep side slopes of the valley and downcutting, boulder and rubble dominated the stream channels. The gravel contents of stream channels were low, and fine sediments were higher than gravel because of the high natural rate of watershed soil erosion. The environment and stability ratings of the streambanks were good.

These streams contain about one fish per 10 feet of stream. Populations were dominated by rainbow trout followed by chinook salmon, Dolly Varden, cutthroat trout, brook trout and sculpin. Besides valley train lands, this was the only geomorphic type occupied by cutthroat trout. Chinook salmon used the lowest sections of the streams for spawning and rearing. Rainbow trout averaged one fish per 15 feet of streams.

Oversteepened Canyon (122)

Geomorphic

These lands ranged from steep to extremely steep. They included moderately to strongly dissected mountain slopes adjacent to the South Fork of the Salmon River. They contained second or third order streams which emptied directly into the main river; therefore, there was a difference of two to four stream orders between streams on this geomorphic type and the South Fork of the Salmon River.

Table 7. (Continued)

Aquatic Environment

No sampling was done in these lands because they made up a very small segment of the study area. The streams were usually very short with extremely steep gradients. Unelss a major tributary breaks through, streams formed within the geomorphic type, would have little to offer the fishery. This description is not valid for the main river, however which does flow through segments of river break lands.

Structural Basin (121)

Geomorphic

This type has been modified or displaced from its original position by faulting activities. It presently occupies a lower position than previously.

Aquatic Environment

Sampling was minimal in these lands because of their scarcity in the study area. The streams were usually located in the headwaters and as a result were very small with low fish population densities.

River Spur (112)

Geomorphic

The river-spur lands were knoll-like ridge remnants, seldom more than 40 acres, adjacent to the South Fork of the Salmon River. They occupied positions formerly occupied by the river. They were separated from the main slopes by the force of the river cutting through fractures and least-resistant rocks.

Aquatic Environment

These isolated tracts did not contain streams and only bordered streams originating in other geomorphic types.

Depositional Geomorphic Process Group

Alluvial Fan (105)

Geomorphic

The alluvial fans were cone-shaped deposits of alluvium, deposited by streams that flowed onto a level plain or met a stream with less energy.

Aquatic Environment

These streams had exceptionally low gradient ratings because of the nature of the fan developing in areas of low gradient. Stream sizes were about average. Stream environments were dominated by riffle; however, the ratio of pool-riffle was close to one (50/50). The low channel gradients and nature of the alluvial fan, promoted high amounts of boulder. Streambank environments were good, but the material of the fan induced a relatively low stability. Channel elevations were about average for all streams sampled.

Chinook salmon used these low gradient streams for rearing and spawning. They were the dominant species followed by rainbow trout, Dolly Varden and sculpin. Chinook salmon averaged one fish per 10 feet of stream while rainbow trout only averaged one fish per 100 feet of stream. The occurrence of sculpin, which, by geomorphic type, were only found with Dolly Varden, rainbow trout, and chinook salmon, indicated a good environment for fish.

Alluvial (101)

Geomorphic

The alluvial lands were immediately adjacent to streams and include river wash, bottom lands, and first terrace land positions. They also occurred in high mountain meadows where they may have a high water table.

Aquatic Environment

Streams in this geomorphic type were large, with low channel gradients as compared to other study streams. The water environments were dominated by riffle but still had a pool-riffle ratio close to 50/50. The stream channel was slightly low in boulder and slightly high in fines, with equal amounts of rubble and gravel. The low gradients and abundant sources of gravel equaled without finding the better spawning environments for salmonids in this geomorphic type. Streambank environment was good. Channel elevations were fairly high (5,614 feet) because these lands occurred mainly in the headwaters of the South Fork of the Salmon River drainage.

Fish densities were high, with one fish per five feet of stream. Chinook salmon were the dominant species followed by brook trout, rainbow trout, Dolly Varden, mountain whitefish, sculpin and dace. More fish species occurred in this geomorphic type than in any other type. Cutthroat trout were absent or had extremely low populations. This was rated the most productive (fishery) of the 26 geomorphic types.

Table 7. (Continued)

Moraine (106)

Geomorphic

The ground moraine materials have been reworked by running water and have had glacial outwash materials deposited on them. They ranged from nearly level to gently sloping with low hummocky relief. Depressions were generally non-cobbly for the first few feet in depth; materials were generally nonstratified.

Aquatic Environment

Stream gradient ratings were fairly low because of the morainal materials dropping in areas of low gradient. Size of stream and channel elevations were about average. Riffle dominated the channels but the pool-riffle ratio was close to one. Pool quality was poor. Possibly because of the materials of the morainal type land, channel substrates were high in percent of gravel and rubble and low in percent fine sediments. Streambank stability was close to excellent, but vegetative streamside cover was less than the average study stream.

Rainbow trout were the dominant species collected, followed by chinook salmon, sculpin, brook trout and Dolly Varden. More sculpin appeared in this geomorphic type per unit of length of stream than in any other geomorphic type. Chinook salmon used the area for spawning and rearing. Total fish collected averaged about one fish per 10 feet of stream.

Glacial Outwash (103)

Geomorphic

This type is similar to moraine lands and makes up the smooth flat landscape in the Warm Lake basin and terrace lands adjacent to the South Fork Salmon River. Its chief distinction from moraine lands is that materials in the outwash lands were stratified while the materials in the moraines were well mixed. Also, glacial outwash land had a smooth micro-relief compared to the hummocky micro-relief of the moraine land.

Aquatic Environment

These lands were restricted to the Warm Lake basin and contained only a few short lower sections of streams. Fish densities were very low, averaging less than one fish per 50 feet of stream. Brook trout was the dominant species followed by rainbow trout.

Sculpin, which had highest populations in environments having the highest total fish populations, was not collected.

Valley Train (104)

Geomorphic

Valley train lands comprised the bottoms and lower side slopes of the U-shaped glacial troughs.

Aquatic Environment

Although this landtype made up only 4.5 percent of the study area, streams in this geomorphic type were the most important of the streams in the higher elevations. Channel gradients were high because the ice-deposited materials had higher valley gradients than water-deposited materials. Because of the wide U-shaped glaciated valley, the streams had excellent buffer zones from overland surface flows and sediment from the valley slopes. Streams were dominated by riffle with a pool-riffle ratio close to one (50/50); pool quality ratings were better than for average streams. Stream channel materials were dominated by boulder and low in gravel. Fine sediments ratings were high for streams having such high gradients. Streambank environments were good; channel elevations were high because all streams were in glaciated valleys.

Fish averaged 2.5 per 50 feet of stream. Rainbow trout was the dominant species followed by Dolly Varden, cutthroat trout, brook trout, and chinook salmon. Sculpin were absent, possible because of the high channel gradients. This geomorphic type was the mainstay of the cutthroat trout and contained the bulk of the Dolly Varden population.

Terrace (102)

Geomorphic

These flat to gently sloping deposits were laid down by major drainages. The deposits were once entrenched and dissected; they are now only remnants of once larger landforms. These river terraces were probably deposited as glacial outwash during one of the Pleistocene glacial intervals and left in their present elevated positions by the entrenchment of streams.

Aquatic Environment

These lands were once the flood plain, but they now hang on the sides of the valley as islands. They did not form or offer much passage

Table 7. (Continued)

to streams except along the main river. Some of these lands were still low enough to be adjacent to the stream.

The streams that did contact these lands were large. Only one station was in terrace lands, and it recorded one fish per five feet of stream. Rainbow trout and chinook salmon were the only fish recorded.

Toe Slope (107)

Geomorphic

At toes of glacial troughs and dissected mountain slopes, the soils of these lands were primarily colluvial deposits at the base of higher adjacent slopes. Slopes were well vegetated (dominantly timber), straight to concave, 30 to 55 percent gradient, 50 to 1,000 feet long, and at elevations of 4,000 to 5,500 feet. Toe slope land occurred in units large enough to delineate consistently at the toes of glacial troughs.

Aquatic Environment

The geomorphic condition of these lands usually precluded perennial streams and this stream scarcity kept them from the random sampling system.

APPENDIX C:

Tables comparing aquatic structural and stream-side environmental conditions with individual environmental variables.

Table 8. Average variable of the stream structure in relation to width of channel.

Variable	Width Class (feet)				
	1-2.9	3-5.9	6-8.9	9-11.9	12-14.9
Gradient (percent)	8	7.5	8.7	7.1	6.1
Width (feet)	2	4	7	10	13
Depth (inches)	4	4	6	8	8
Riffle (percent)	50	50	42	50	54
Pool (percent)	50	50	58	50	46
Pool Rating (units)	4.3	4.3	4	3.7	3.8
Channel Composition (percent)					
Boulder	14	22	33	33	36
Rubble	13	26	22	23	26
Gravel	43	33	25	21	17
Fine sediment	30	19	20	23	21
Bank Environment (units)					
Cover	1.5	1.6	1.7	1.8	1.8
Condition	1.8	1.8	1.7	1.5	1.7
Type	2.0	1.9	1.9	1.9	1.9
Channel Elevation (feet)	5897	5952	6135	5551	5620
Sample Size	43	325	398	424	322

Table 8. (Continued)

Variable	Width Class (feet)				
	15-17.9	18-20.9	21-23.9	24-26.9	27-29.9
Gradient (percent)	6.1	6.6	6.8	6.2	7.0
Width (feet)	16	19	22	25	28
Depth (inches)	9	10	10	10	10
Riffle (percent)	50	57	59	60	65
Pool (percent)	50	43	41	40	35
Pool Rating (units)	3.8	3.7	3.6	3.7	4.0
Channel Composition (percent)					
Boulder	37	42	40	38	45
Rubble	26	27	28	30	29
Gravel	15	12	15	13	12
Fine sediment	22	19	17	19	14
Bank Environment (units)					
Cover	1.8	1.8	1.7	1.7	1.7
Condition	1.6	1.5	1.6	1.6	1.6
Type	1.9	1.9	1.9	1.9	1.9
Channel Elevation (feet)	5417	5250	5123	5132	4979
Sample Size	283	267	125	121	54

Table 8. (Continued)

Variable	Width Class (feet)				
	30-32.9	33-35.9	36-38.9	39-41.9	42-44.9
Gradient (percent)	4.7	4.9	9.9	4.3	4.9
Width (feet)	31	33	37	40	44
Depth (inches)	12	12	11	13	13
Riffle (percent)	62	45	63	50	62
Pool (percent)	38	55	37	50	38
Pool Rating (units)	3.7	3.2	3.8	2.5	3.6
Channel Composition (percent)					
Boulder	38	41	41	24	44
Rubble	30	26	38	33	29
Gravel	12	10	11	12	9
Fine sediment	20	23	10	31	18
Bank Environment (units)					
Cover	1.7	1.8	1.6	1.8	1.7
Condition	1.4	1.5	1.5	1.4	1.3
Type	1.8	1.8	1.9	1.7	0.5
Channel Elevation (feet)	4968	4924	4610	4864	5126
Sample Size	57	29	11	12	9

Table 9. Average variable of the stream structure in relation to depth of stream.

Variable	Depth Class (inches)					
	0-2.9	3-5.9	6-8.9	9-11.9	12-14.9	15-17.9
Gradient (percent)	7.1	7.9	6.8	6.5	6.5	6.0
Width (feet)	5	9	14	16	17	19
Depth (inches)	2	4	7	10	13	16
Riffle (percent)	80	67	64	50	35	32
Pool (percent)	20	33	36	50	65	68
Pool Rating (units)	4.7	4.6	4.2	3.6	2.8	2.2
Channel Composition (percent)						
Boulder	18	31	37	38	32	42
Rubble	23	26	28	26	21	20
Gravel	38	28	17	14	15	8
Fine sediment	21	15	18	22	32	30
Bank Environment (units)						
Cover	1.6	1.7	1.8	1.8	1.7	1.6
Condition	1.8	1.8	1.7	1.6	1.5	1.6
Type	2.0	1.9	1.9	1.9	1.8	1.8
Channel Elevation (feet)	5832	5931	5600	5444	5402	5191
Sample Size	110	708	762	491	224	91

Table 9. (Continued)

Variable	Depth Class (inches)					
	18-20.9	21-23.9	24-27	27-29.9	30-32.9	33-35.9
Gradient (percent)	6.1	5.8	5.8	15.0	23.0	3.0
Width (feet)	18	24	20	32	17	9
Depth (inches)	19	22	25	29	31	34
Riffle (percent)	28	17	5	41	0	0
Pool (percent)	72	83	95	59	100	100
Pool Rating (units)	2.2	1.7	1.4	1.0	1.0	1.0
Channel Composition (percent)						
Boulder	37	39	26	100	100	0
Rubble	11	9	14	0	0	0
Gravel	15	10	16	0	0	0
Fine sediment	37	42	44	0	0	100
Bank Environment (units)						
Cover	1.6	1.5	1.6	1.5	1.8	1.0
Condition	1.6	1.6	1.6	1.5	2.0	2.0
Type	1.7	1.6	1.6	2.0	2.0	1.0
Channel Elevation (feet)	5215	5203	5699	6160	5000	7530
Sample Size	56	23	10	1	1	1

Table 10. Stream variable relation to percent channel gradient.

	Gradient Mean							
Variable	1.0	2.0	3.0	4.1	5.0	6.0	7.0	8.0
Width (feet)	12	14	16	15	14	12	13	12
Depth (inches)	10	8	9	8	7	7	8	8
Riffle (percent)	33	43	56	60	57	58	54	58
Pool (percent)	67	57	44	40	43	42	46	42
Pool Rating (units)	3.0	3.5	3.6	4.1	4.0	3.9	3.8	4.0
Channel Composition (percent)								
Boulder	7	11	22	33	34	39	41	46
Rubble	14	20	31	32	32	26	30	20
Gravel	19	34	23	20	14	21	15	17
Fine sediment	60	35	24	15	20	14	14	17
Bank Environment (units)								
Cover	1.8	1.7	1.6	1.8	1.7	1.7	1.8	1.8
Condition	1.4	1.5	1.5	1.7	1.7	1.8	1.7	1.6
Type	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.8
Channel Elevation (feet)	5,730	5,725	5,347	5,521	5,556	5,548	5,645	5,738
Sample Size	99	217	347	375	312	249	120	133

Table 10. (Continued)

Variable	Gradient Mean 9.0	10.0	11.1	12.0	13.0	14.0	15.0	16.0
Width (feet)	12	12	12	14	12	6	12	7
Depth (inches)	8	8	5	8	8	7	8	5
Riffle (percent)	58	50	58	50	42	33	50	57
Pool (percent)	42	50	42	50	58	67	50	43
Pool Rating (units)	3.9	3.5	4.3	3.9	3.8	3.7	3.8	4.5
Channel Composition (percent)								
Boulder	48	38	37	50	56	24	56	44
Rubble	22	20	23	17	17	5	17	32
Gravel	15	22	27	14	20	48	11	19
Fine sediment	15	20	13	19	7	23	16	5
Bank Environment (units)								
Cover	1.5	1.9	1.7	1.8	1.6	1.8	1.6	1.6
Condition	1.7	1.5	1.9	1.8	2.0	2.0	1.8	1.9
Type	1.9	1.8	2.0	1.9	2.0	2.0	1.9	2.0
Channel Elevation (feet)	5,471	5,879	5,984	5,563	6,103	6,599	5,497	6,384
Sample Size	75	66	54	79	36	40	69	31

Table 10. (Continued)

Variable	Gradient Mean 17.0	18.0	19.0	20.0	21.0	22.0	23.0	24.0
Width (feet)	11	9	12	9	18	11	15	6
Depth (inches)	7	5	7	7	7	9	14	5
Riffle (percent)	64	56	50	56	50	64	20	50
Pool (percent)	36	44	50	44	50	36	80	50
Pool Rating (units)	4.4	4.2	4.3	2.2	3.5	3.3	2.5	5.0
Channel Composition (percent)								
Boulder	58	61	59	46	77	34	92	23
Rubble	21	10	29	19	17	34	2	12
Gravel	17	16	6	20	1	6	0	40
Fine sediment	4	13	6	15	5	26	6	25
Bank Environment (units)								
Cover	1.7	1.6	1.6	1.6	1.8	2.0	1.7	1.9
Condition	1.7	1.7	2.0	1.4	1.9	1.7	2.0	1.4
Type	2.0	1.8	1.9	1.7	2.0	2.0	2.0	1.8
Channel Elevation (feet)	5,834	5,970	5,807	6,313	4,800	5,920	5,000	6,290
Sample Size	38	29	15	20	5	6	5	5

Table 10. (Continued)

Variable	Gradient Mean 25.0	30.0	32.0	35.0	40.0
Width (feet)	8	12	11	20	27
Depth (inches)	6	7	13	9	11
Riffle (percent)	50	83	73	65	96
Pool (percent)	50	17	27	35	4
Pool Rating (units)	4.0	4.0	4.5	4.0	4.0
Channel Composition (percent)					
Boulder	56	69	68	73	100
Rubble	23	18	24	16	0
Gravel	6	3	2	5	0
Fine sediment	15	10	6	6	0
Bank Environment (units)					
Cover	1.5	1.7	2.0	1.5	1.5
Condition	1.7	1.4	2.0	1.0	1.0
Type	1.7	1.8	2.0	2.0	2.0
Channel Elevation (feet)	5,730	6,580	5,760	7,100	-
Sample Size	10	15	5	5	5

Table 11. Variables of the stream in relation to rating of stream pools.

Variable	Pool Rating				
	1	2	3	4	5
Gradient (percent)	5.6	5.8	5.9	8.3	6.7
Width (feet)	19	15	13	13	14
Depth (inches)	16	12	9	8	6
Riffle width (percent)	11	20	15	54	71
Pool width (percent)	89	80	85	46	29
Channel Composition (percent)					
Boulder	19	26	24	39	38
Rubble	15	21	22	23	28
Gravel	18	15	23	20	21
Fine sediment	48	38	31	18	13
Bank Environment (units)					
Cover	1.7	1.8	1.8	1.7	1.7
Condition	1.5	1.5	1.6	1.7	1.8
Type	1.8	1.8	1.9	1.8	1.9
Channel Elevation (feet)	5592	5556	5701	5606	5616
Sample Size	163	177	327	574	810

Table 12. Variables of the stream in relation to the cover rating of the streambanks.

Variable	Bank Cover Rating 0-1.0	1.1-2.0
Gradient (percent)	4.2	7.1
Width (feet)	10	14
Depth (inches)	9	8
Riffle Width (percent)	41	57
Pool Width (percent)	59	43
Pool Rating (units)	3.5	3.8
Channel Materials (percent)		
Boulder	15	35
Rubble	17	26
Gravel	39	19
Fine sediment	30	20
Streambank Environment (units)		
Cover	1.0	1.8
Condition	1.8	1.7
Type	1.8	1.9
Channel Elevation (feet)	5816	5622
Sample Size	288	4412

Table 13. Variables of the stream in relation to condition of the streambanks.

Variable	Average Condition Rating 1.0	1.9
Gradient (percent)	6.4	7.2
Width (feet)	15	13
Depth (inches)	9	8
Riffle Width (percent)	53	54
Pool Width (percent)	47	46
Pool rating (units)	3.4	3.9
Channel Composition (percent)		
Boulder	25	37
Rubble	28	24
Gravel	15	22
Fine sediment	32	17
Bank Environment (units)		
Cover	1.8	1.7
Condition	1.0	1.9
Type	1.8	1.9
Channel Elevation (feet)	5601	5644
Sample Size	1190	3756

Table 14. Variables of the stream in relation to the type rating of the streambank.

Variable	Bank Type Rating 0.0-1.4	Bank Type Rating 1.5-2.0
Gradient (percent)	5.5	7.1
Width (feet)	14	13
Depth (inches)	10	8
Riffle Width (percent)	43	46
Pool Width (percent)	57	54
Pool Rating (units)	3.3	3.9
Channel Materials (percent)		
Boulder	21	36
Rubble	24	26
Gravel	21	20
Fine sediment	34	18
Streambank Environment (units)		
Cover	1.7	1.7
Condition	1.5	1.7
Type	1.1	2.0
Channel Elevation (feet)	5922	5601
Sample Size	510	4438

Table 15. Variables of the stream structure in relation to stream order.

Variable	Order 1	2	3	4	5
Gradient (percent)	10	8	7	6	4
Width (feet)	7	9	12	20	21
Depth (inches)	4	7	8	10	9
Riffle (percent)	57	56	50	60	64
Pool (percent)	43	44	50	40	33
Pool rating (units)	4	4	4	4	4
Channel composition (percent)					
Boulder	32	31	29	45	40
Rubble	16	22	27	25	38
Gravel	37	24	21	13	10
Fine sediment	15	23	23	17	12
Bank Environment (units)					
Cover	1.7	2.0	2.0	2.0	1.7
Condition	1.9	2.0	2.0	2.0	1.8
Type	1.9	2.0	2.0	2.0	1.9
Channel Elevation (feet)	6961	6178	5593	5060	4467
Sample Size	153	526	1022	588	144
Percent of Study Area	53	25	14	4	1

Table 16. Variables of the stream in relation to elevation of the stream channel.

Variable	Channel Elevation						
	3,600 3,799	3,800 3,999	4,000 4,199	4,200 4,399	4,400 4,599	4,600 4,799	4,800 4,999
Gradient (percent)	11	5	5.6	6.6	5.6	10.5	8.7
Width (feet)	10	16	18	18	18	15	15
Depth (inches)	7	8	8	9	9	8	8
Riffle (percent)	60	69	61	61	61	60	53
Pool (percent)	40	31	39	39	39	40	47
Pool Rating (units)	4.6	4.5	4.1	4.1	4.0	3.8	3.9
Channel Composition (percent)							
Boulder	52	42	28	45	49	51	39
Rubble	24	39	35	25	24	19	27
Gravel	5	13	14	13	10	8	14
Fine sediment	19	6	23	17	17	22	20
Bank Environment (units)							
Cover	1.5	1.4	1.6	1.7	1.8	1.8	1.7
Condition	2.0	1.8	1.9	1.8	1.6	1.7	1.8
Type	1.9	1.9	1.9	1.9	2.0	2.0	2.0
Mean Elevation (feet)	3,653	3,905	4,101	4,297	4,483	4,676	4,919
Sample Size	15	50	55	115	101	65	85

Table 16. (Continued)

Variable	Channel Elevation in Feet 5,000–5,199	5,200–5,399	5,400–5,599	5,600–5,799	5,800–5,999	6,000–6,199	6,200–6,399
Gradient (percent)	6	6.2	3.8	7.2	6.5	6.2	6.8
Width (feet)	20	18	14	14	12	11	9
Depth (inches)	9	9	9	8	7	7	6
Riffle (percent)	65	56	50	50	50	45	45
Pool (percent)	35	44	50	50	50	55	55
Pool Rating (units)	3.7	3.8	3.6	3.6	3.8	3.6	3.6
Channel Composition (percent)							
Boulder	37	38	21	35	30	22	22
Rubble	36	30	24	28	30	29	23
Gravel	11	13	23	18	24	25	28
Fine sediment	16	19	32	19	16	24	27
Bank Environment (units)							
Cover	1.8	1.7	1.8	1.8	1.7	1.7	1.8
Condition	1.4	1.6	1.6	1.7	1.8	1.5	1.5
Type	1.9	1.9	1.8	1.9	1.9	1.9	1.9
Mean Elevation (feet)	5,097	5,288	5,485	5,688	5,898	6,094	6,282
Sample Size	155	190	350	205	170	190	160

Table 16. (Continued)

Variable	Channel Elevation in Feet 6,400–6,599	6,600–6,799	6,800–6,999	7,000–7,199	7,200–7,399	7,400–7,599	7,600–7,799
Gradient (percent)	8.5	10.3	9.1	10.8	7.6	10.8	14
Width (feet)	9	8	9	8	7	7	6
Depth (inches)	5	6	6	4	5	8	3
Riffle (percent)	55	50	45	63	43	29	67
Pool (percent)	45	50	55	37	57	71	33
Pool Rating (units)	4.1	4.1	4.1	4.6	4.3	3.9	5.0
Channel Composition (percent)							
Boulder	34	43	38	32	40	22	52
Rubble	20	16	15	30	14	15	0
Gravel	25	31	29	26	33	41	36
Fine sediment	21	10	18	12	13	22	12
Bank Environment (units)							
Cover	1.8	1.8	1.8	1.7	1.7	1.6	2
Condition	1.7	1.9	1.8	1.8	1.9	1.8	2
Type	1.8	1.8	1.8	2.0	1.9	1.7	2
Mean Elevation (feet)	6,485	6,692	6,869	7,092	7,256	7,494	7,640
Sample Size	100	90	90	50	54	45	5

APPENDIX D:

Tables comparing fish population numbers, length, and species with aquatic structural variables.

Table 17. Average per station of fish numbers and length (within parenthesis) by species to streamside cover.

	Cover			
	Exposed	Grass	Brush	Forest
Total Fish	1.5(2.9)	7.2 (2.7)	6.4 (2.7)	2.4 (3.0)
Chinook salmon		3.9 (0.5)	1.8 (0.4)	0.7 (0.2)
Rainbow trout		1.0 (1.3)	3.9 (2.1)	0.8 (1.4)
Cutthroat trout		0.1 (0.5)	0.1 (0.2)	0.2 (0.4)
Dolly Varden	1.5(2.9)	0.9 (1.2)	0.3 (0.7)	0.4 (1.1)
Brook trout		0.4 (0.6)	0.1 (0.3)	0.2 (0.4)
Sculpin		0.4 (0.5)	0.1 (0.2)	0.1 (0.2)
Mountain whitefish		0.3 (0.1)	0.02(0.1)	0.02(0.1)
Dace		0.04(0.1)	0.01(0.02)	
Other		0.1 (0.2)	0.1 (0.2)	
Sample Number	2	27	107	155

Table 18. Average per station of fish numbers and length (within parenthesis) by species to condition and type of the streambank.

	Condition				Type			
	Poor	Fair	Good	Excellent	Poor	Fair	Good	Excellent
Total Fish	3.5(2.2)	4.2 (3.4)	3.9(3.1)	4.8 (2.6)	1.3(2.0)	4.7 (3.2)	3.3(2.7)	4.4 (2.9)
Chinook salmon	1.6(0.3)	1.9 (0.3)	1.2(0.3)	1.3 (0.2)		1.5 (0.1)	0.5(0.3)	1.5 (0.3)
Rainbow trout	0.5(1.2)	1.2 (1.8)	2.1(1.9)	2.6 (1.5)		1.6 (1.8)	2.4(1.7)	1.9 (1.6)
Cutthroat trout		0.2 (0.3)	0.1(0.3)	0.2 (0.4)		0.2 (0.6)	0.2(0.5)	0.1 (0.3)
Dolly Varden	0.4(0.6)	0.5 (1.6)	0.3(0.6)	0.5 (0.9)	1.0(1.3)	0.5 (0.9)	0.2(0.4)	0.4 (1.0)
Brook trout	0.9(0.7)	0.2 (0.1)	0.2(0.6)	0.1 (0.3)		4.0 (0.6)		0.2 (0.4)
Sculpin	0.3(0.3)	0.1 (0.2)	0.1(0.1)	0.2 (0.2)	0.3(0.7)	0.2 (0.2)	0.1(0.3)	0.1 (0.2)
Mtn. Whitefish	0.1(0.2)	0.1 (0.2)		0.03(0.2)		0.3 (0.1)		0.02 (0.1)
Dace		0.03(0.1)				0.04(0.1)		0.004(0.01)
Other			0.1(0.1)	0.04(0.1)				0.04 (0.1)
Sample Number	20	66	91	113	3	25	26	237

Table 19. Average per station of fish numbers and length (within parenthesis) by species to percent of fine sediment in the stream channel.

	Fine Sediment in Percent						
	0-4	5-9	10-14	15-19	20-24	25-29	30-34
Total fish	4.0 (2.8)	5.9 (3.3)	4.6 (3.3)	4.8 (3.6)	4.5 (2.4)	2.3(3.6)	3.3 (1.9)
Chinook salmon	0.6 (0.2)	1.8 (0.4)	1.5 (0.3)	1.2 (0.2)	2.4 (0.3)	0.4(0.1)	1.4 (0.3)
Rainbow trout	2.8 (1.8)	3.3 (2.3)	2.6 (2.4)	2.2 (1.3)	1.4 (1.2)	1.5(3.3)	0.7 (0.7)
Cutthroat trout	0.3 (0.5)	0.1 (0.1)	0.03(0.1)	0.03(0.2)	0.3 (0.9)		0.05(0.2)
Dolly Varden	0.1 (0.5)	0.5 (1.3)	0.3 (0.9)	1.1 (1.9)	0.03(0.2)	0.2(0.3)	0.6 (1.3)
Brook trout	0.04(0.3)	0.04(0.3)	0.1 (0.3)	0.2 (0.4)	0.1 (0.3)		0.1 (0.3)
Sculpin	0.1 (0.2)	0.1 (0.3)	0.03(0.1)	0.1 (0.1)	0.2 (0.4)	0.2(0.1)	0.3 (0.3)
Mtn. Whitefish	0.02(0.2)	0.02(0.2)	0.03(0.3)	0.03(0.05)			0.05(0.1)
Dace							
Other	0.04(0.1)	0.1 (0.3)	0.1 (0.1)		0.03(0.1)		
Sample Number	49	45	37	35	33	17	22

Table 19. (Continued)

	Fine Sediment in Percent						
	35-39	40-44	45-49	50-54	55-59	60-64	65-69
Total fish	7.8(4.4)	1.8(1.5)	1.4(1.9)	5.7(2.0)	2.2(3.5)	0.5(1.8)	10.0(1.7)
Chinook salmon	3.7(0.3)	1.1(0.3)	0.2(0.3)	3.5(0.9)			6.0(0.6)
Rainbow trout	1.2(2.8)	0.3(0.6)		0.8(1.7)			
Cutthroat trout	0.2(0.5)				0.8(1.0)		
Dolly Varden	0.5(1.2)	0.3(1.2)	0.9(1.7)	0.2(0.2)	1.4(2.5)		
Brook trout	1.0(1.5)			1.0(1.2)		0.5(1.8)	4.0(1.0)
Sculpin	0.3(0.5)	0.1(0.4)	0.3(0.2)				
Mtn. whitefish	0.8(0.3)						
Dace	0.1(0.2)			0.2(0.4)			
Other							
Sample Number	10	8	10	6	5	2	3

Table 19. (Continued)

	Fine Sediment in Percent					
	70-74	75-79	80-84	85-89	90-94	95-100
Total fish		0.7(0.9)			6.0(4.0)	2.0(1.9)
Chinook salmon						
Rainbow trout						
Cutthroat trout						
Dolly Varden						2.0(1.9)
Brook trout		0.7(0.9)			6.0(4.0)	
Sculpin						
Mtn. whitefish						
Dace						
Other						
Sample Number	2	3	1	0	1	2

Table 20. Average per station of fish numbers and length (within parenthesis) by species to percent of rubble in stream channel.

	Percent Rubble							
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Total fish	2.4(1.9)	1.6(1.9)	4.2(4.2)	3.6 (2.6)	2.1(2.9)	6.2 (3.7)	3.2 (3.1)	4.8 (3.5)
Chinook salmon	0.9(0.1)	0.2(0.2)	0.3(0.3)	1.5 (0.3)	0.3(0.2)	1.6 (0.3)	0.7 (0.1)	2.0 (0.3)
Rainbow trout	0.3(0.3)	0.8(0.5)	2.8(3.3)	0.9 (1.2)	1.1(1.9)	3.3 (2.6)	1.1 (1.3)	1.9 (1.8)
Cutthroat trout	0.2(0.3)			0.3 (0.9)		0.3 (0.6)	0.4 (0.7)	0.1 (0.3)
Dolly Varden	0.4(0.7)	0.4(1.0)	0.3(0.8)	0.1 (0.4)	0.3(0.8)	0.8 (1.7)	0.8 (1.7)	0.5 (1.3)
Brook trout	0.4(0.6)	0.2(0.3)	0.7(0.4)	0.4 (0.6)	0.2(0.5)	0.03(0.2)	0.2 (0.1)	0.03(0.2)
Sculpin	0.2(0.1)	0.1(0.1)	0.2(0.4)	0.2 (0.1)	0.1(0.2)	0.1 (0.2)		0.1 (0.3)
Mtn. whitefish				0.2 (0.1)	0.1(0.4)			
Dace				0.03(0.1)			0.04(0.1)	
Other					0.1(0.1)	0.1 (0.2)		0.03(0.2)
Sample Number	20	25	20	33	33	29	28	29

Table 20. (Continued)

	Percent Rubble							
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79
Total fish	6.4(2.4)	3.2(2.9)	6.8(1.7)	14.4(3.4)	10.3(1.9)	3.0(2.5)	11.6(2.9)	1.3(3.0)
Chinook salmon	2.4(0.5)	0.4(0.3)	4.1(0.6)	7.6(0.7)	7.8(0.7)	0.3(0.3)	0.8(0.4)	
Rainbow trout	2.9(1.1)	1.8(2.2)	2.4(1.8)	5.6(2.2)	1.5(2.1)	2.4(1.3)	10.6(2.6)	
Cutthroat trout	0.5(1.2)						0.2(1.4)	
Dolly Varden	0.1(0.1)	0.4(0.2)		0.4(0.6)	0.2(0.9)	0.4(1.3)		1.3(3.0)
Brook trout	0.2(0.3)	0.3(0.9)			0.2(1.4)			
Sculpin			0.2(0.2)	0.6(1.4)	0.5(1.0)			
Mtn. whitefish		0.1(0.6)		0.2(1.3)	0.2(0.3)			
Dace								
Other	0.2(0.3)	0.1(0.1)						
Sample Number	17	18	9	8	6	8	5	3

Table 21. Average per station of fish numbers and length (within parenthesis) by species to percent of gravel in stream channel.

	Percent Gravel							
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Total fish	4.5 (3.6)	3.5 (2.6)	5.8 (3.1)	6.0(2.6)	2.7(3.3)	1.1(2.5)	3.2(2.8)	17.3(2.4)
Chinook salmon	0.6 (0.3)	0.8 (0.4)	2.3 (0.2)	2.5(0.2)	1.2(0.2)	0.2(0.2)	1.5(0.2)	12.8(0.7)
Rainbow trout	3.1 (2.5)	1.9 (1.7)	2.7 (1.8)	2.0(1.5)	0.7(1.6)	0.2(0.3)	0.4(0.8)	1.0(0.4)
Cutthroat trout	0.2 (0.4)	0.5 (0.1)	0.2 (0.6)	0.2(0.4)		0.1(0.3)	0.2(0.4)	0.2(1.0)
Dolly Varden	0.4 (0.7)	0.2 (0.5)	0.4 (1.1)	0.5(1.3)	0.6(1.2)	0.3(1.6)	1.0(1.8)	
Brook trout	0.1 (0.3)	0.3 (0.5)	0.1 (0.4)	0.4(0.2)	0.2(0.4)	0.1(0.4)	0.1(0.6)	1.3(1.0)
Sculpin	0.04(0.1)	0.05(0.1)	0.2 (0.3)	0.3(0.5)		0.3(0.2)		0.5(0.6)
Mtn. whitefish	0.01(0.1)	0.03(0.2)	0.04(0.3)					1.3(0.4)
Dace		0.02(0.04)						0.2(0.3)
Other	0.04(0.1)	0.1 (0.3)						
Sample Number	67	64	46	33	18	11	12	6

Table 21. (Continued)

	Percent Gravel									
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89
Total fish	1.5(1.7)	0.3(1.4)	8.0(5.6)	4.3(3.1)	1.3(1.9)		1.0(2.4)		4.5(3.9)	2.0(3.0)
Chinook salmon	0.2(0.4)		1.0(2.0)	1.5(0.6)						
Rainbow trout	0.5(0.7)		3.0(4.2)	0.8(0.5)	1.3(1.9)					
Cutthroat trout										
Dolly Varden	0.6(1.1)	0.3(1.4)	1.0(4.2)	1.3(2.6)			1.0(2.4)		2.5(2.5)	2.0(3.0)
Brook trout	0.2(0.4)								0.5(2.0)	
Sculpin			3.0(2.7)	0.8(0.5)					1.5(1.2)	
Mtn. whitefish										
Dace										
Other										
Sample Number	13	4	4	4	4	1	1	0	1	1

Table 22. Average per station of fish numbers and length (within parenthesis) by species to percent of boulder in stream channel.

	Percent Boulder							
	0-4	5-9	10-14	15-19	20-24	25-29	30-34	35-39
Total fish	3.5(2.6)	9.1(2.7)	3.8(2.4)	1.2(1.7)	4.5(2.1)	4.8(1.7)	2.4(2.5)	3.7(3.1)
Chinook salmon	0.6(0.2)	5.9(0.5)	2.5(0.5)	0.2(0.2)	0.6(0.3)	4.3(0.3)	0.6(0.4)	1.4(0.6)
Rainbow trout	1.4(0.8)	1.4(1.8)	0.5(0.6)	0.1(0.3)	3.4(1.4)	0.3(1.1)	0.6(1.0)	1.4(2.4)
Cutthroat trout	0.1(0.2)		0.1(0.5)				0.2(0.6)	0.3(0.4)
Dolly Varden	0.8(1.6)	0.5(0.9)	0.5(1.1)	0.4(0.9)	0.2(0.5)	0.1(0.4)	0.9(0.1)	0.1(0.4)
Brook trout	0.4(0.5)	0.6(0.5)	0.1(0.3)			0.1(0.5)	0.6(0.1)	0.1(0.3)
Sculpin	0.2(0.3)	0.2(0.3)	0.1(0.2)	0.5(0.5)	0.2(0.3)		0.1(0.1)	0.1(0.1)
Mtn. whitefish		0.3(0.1)	0.1(0.1)		0.1(0.6)			0.1(0.9)
Dace		0.1(0.2)						
Other								0.2(0.5)
Sample Number	54	26	18	13	17	12	14	14

Table 22. (Continued)

	Percent Boulder							
	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79
Total fish	3.3(2.4)	9.1(4.6)	4.1(4.1)	7.4(5.0)	3.6(3.4)	1.5(3.1)	2.5(3.0)	2.9(2.6)
Chinook salmon		5.0(0.8)		1.3(0.5)				0.7(0.5)
Rainbow trout	2.7(1.5)	3.0(3.6)	2.9(2.9)	5.5(4.1)	3.1(2.0)	0.8(1.9)	1.7(0.8)	1.9(2.2)
Cutthroat trout	0.3(0.6)		0.4(0.8)	0.2(0.2)		0.3(0.9)	0.2(0.5)	0.3(0.4)
Dolly Varden	0.1(0.4)	0.7(1.8)	0.6(1.2)	0.3(1.4)	0.2(0.9)	0.4(1.1)	0.1(0.5)	
Brook trout	0.3(0.6)		0.1(0.3)		0.2(1.1)	0.1(0.6)	0.2(0.4)	
Sculpin		0.1(0.3)	0.1(0.1)	0.1(0.2)	0.2(0.3)		0.1(0.2)	
Mtn. whitefish							0.1(0.7)	
Dace								
Other		0.3(4.9)		0.1(0.4)			0.2(0.4)	
Sample Number	18	10	19	18	11	13	13	11

Table 22. (Continued)

	80-84	85-89	90-94	95-100
Total fish	6.3(2.2)	2.0(3.1)		6.0(6.3)
Chinook salmon	0.5(0.7)			
Rainbow trout	5.5(2.2)	1.8(1.1)		6.0(6.3)
Cutthroat trout				
Dolly Varden		0.3(2.0)		
Brook trout				
Sculpin	0.3(1.1)			
Mtn. whitefish				
Dace				
Other				
Sample Number	4	4	1	1

Table 23. Average per station of fish numbers and length (within parenthesis) by species to quality of pool.

	Pool Quality				
	Excellent	Good	Fair	Poor	Very Poor
Total Fish	8.1(4.5)	2.3(2.5)	2.5(2.6)	4.5 (2.9)	5.4 (3.1)
Chinook salmon	4.6(0.4)	0.1(0.2)	0.7(0.1)	1.8 (0.3)	1.1 (0.4)
Rainbow trout	0.9(3.1)	0.8(0.7)	0.8(1.1)	2.2 (2.1)	3.3 (1.9)
Cutthroat trout			0.3(0.1)	0.2 (0.5)	0.2 (0.5)
Dolly Varden	0.7(1.0)	0.6(1.2)	0.6(1.2)	0.2 (0.6)	0.4 (1.1)
Brook trout	1.2(0.6)	0.4(0.6)	0.1(0.3)	0.03(0.2)	0.1 (0.3)
Sculpin	0.3(0.4)	0.3(0.4)	0.3(0.3)	0.02(0.04)	0.1 (0.3)
Mtn. Whitefish	0.4(0.1)			0.02(0.03)	0.04(0.3)
Dace	0.1(0.1)				
Other				0.1 (0.1)	0.1 (0.2)
Sample Number	18	28	34	60	98

Table 24. Average per station of fish numbers and length (within parenthesis) by species to percent of channel in pool.

	Percent of Channel in Pool								
	0-10	10.1-20	20.1-30	30.1-40	40.1-50	50.1-60	60.1-70	70.1-80	80.1-90
Total fish		10.1(2.0)	4.6 (3.2)	5.2(2.9)	5.1 (2.3)	4.4 (3.9)	1.8(2.5)	1.7(2.5)	1.3(1.9)
Chinook salmon		8.3(0.9)	1.4 (0.4)	1.3(0.4)	1.0 (0.3)	1.9 (0.3)	0.1(0.1)	0.1(0.9)	
Rainbow trout		0.9(1.8)	2.3 (1.9)	3.4(2.1)	3.1 (1.0)	1.1 (2.3)	0.1(1.4)	0.1(0.3)	
Cutthroat trout			0.2 (0.5)	0.1(0.2)	0.3 (0.5)	0.1 (0.3)	0.1(0.1)	0.8(1.5)	
Dolly Varden		0.2(0.9)	0.4 (1.2)	0.3(0.7)	0.4 (0.4)	0.4 (1.1)	0.5(1.2)	0.7(0.2)	0.7(1.2)
Brook trout		0.2(0.3)	0.04(0.1)	0.1(0.5)	0.04(0.2)	0.4 (0.7)	0.1(0.2)		0.6(0.8)
Sculpin		0.2(0.3)	0.1 (0.1)	0.1(0.2)	0.2 (0.3)	0.3 (0.3)	0.2(0.2)		
Mtn. whitefish		0.2(1.2)	0.02(0.2)		0.02(0.2)	0.2 (0.1)			
Dace						0.04(0.1)			
Other		0.2(0.2)	0.1 (0.1)	0.1(0.2)	0.04(0.1)				
Sample Number	2	13	56	57	46	52	33	17	15

Table 25. Average per station of fish numbers and length (within parenthesis) by species to feature of pool.

	Feature						
	No Pool	Boulder	Log	Meander	Bank	Debris	Sand Bar
Total fish	3.0 (2.4)	4.7 (3.4)	4.2(2.6)	5.5(2.7)	18.0(1.9)	3.8 (3.3)	12.0(2.1)
Chinook salmon	1.6 (0.3)	0.7 (0.3)	2.9(0.3)	2.2(0.2)	18.0(1.9)	1.9 (0.3)	6.0(2.2)
Rainbow trout	0.8 (1.0)	3.1 (2.0)	0.5(1.1)	0.7(1.2)		0.5 (2.1)	3.0(1.8)
Cutthroat trout	0.04(0.2)	0.2 (0.4)	0.1(0.3)				
Dolly Varden	0.3 (1.0)	0.3 (0.8)	0.5(1.4)	0.7(1.2)		0.7 (1.0)	
Brook trout	0.1 (0.3)	0.1 (0.3)		0.9(0.8)		0.5 (0.6)	
Sculpin	0.1 (0.1)	0.1 (0.2)	0.2(0.2)	0.5(0.4)		0.1 (0.2)	3.0(2.1)
Mountain whitefish		0.01(0.1)	0.1(0.4)	0.5(0.2)		0.03(0.1)	
Dace	0.02(0.05)			0.1(0.1)			
Other		0.1 (0.2)					
Sample Number	54	150	31	17	1	37	1

Table 26. Average per station of fish numbers and length* (within parenthesis) by species to gradient of the stream channel.

	Gradient (percent)					
	2	3	4	5	6	7
Fish per sample	1.5(2.5)	4.6(2.6)	8.5(3.0)	7.9 (3.2)	6.6 (3.6)	2.4 (3.1)
Chinook salmon	0.3(0.5)	1.7(0.5)	3.0(0.7)	2.8 (0.6)	3.1 (0.4)	0.4 (0.2)
Rainbow trout		0.8(1.3)	3.9(2.2)	4.2 (2.3)	2.3 (1.7)	1.0 (1.8)
Cutthroat trout			0.1(0.3)	0.1 (0.3)	0.1 (0.1)	0.1 (0.4)
Dolly Varden	0.2(0.9)	0.5(1.4)	0.5(0.7)	0.4 (1.1)	0.9 (1.6)	0.6 (1.4)
Brook trout	0.5(1.3)	0.9(0.7)	0.5(0.4)	0.1 (0.2)	0.1 (0.7)	
Sculpin	0.5(0.3)	0.7(0.6)	0.2(0.3)	0.2 (0.5)	0.1 (0.2)	0.1 (0.2)
Mtn. whitefish			0.2(0.1)	0.03(1.0)	0.1 (0.5)	0.03(0.4)
Dace			0.1(0.1)			
Other			0.2(0.3)	0.3 (0.2)	0.04(0.04)	0.03(0.2)
Sample Number	6	15	40	31	47	27

*Average length (inches) represent the average of all the total lengths of the total fish or total individual species per station.

Table 26. (Continued)

	Gradient (percent)					
	8	9	10	11	12	13
Fish per sample	3.3 (4.0)	1.7(2.8)	3.3(2.6)	1.3(3.2)	0.7(2.2)	
Chinook salmon	0.6 (0.1)		0.3(0.2)			
Rainbow trout	2.1 (2.7)	1.0(1.4)	2.4(1.9)	0.6(1.6)		
Cutthroat trout	0.4 (0.6)		0.5(0.9)	0.2(0.7)	0.5(0.8)	
Dolly Varden	0.2 (0.6)	0.7(1.8)		0.3(0.9)	0.2(1.4)	
Brook trout	0.03(0.2)	0.1(0.5)		0.1(0.6)		
Sculpin	0.03(0.1)			0.1(0.1)		
Mtn. whitefish						
Dace						
Other						
Sample Number	28	15	12	21	6	5

Average length (inches) represent the average of all the total lengths of the total fish or total individual species per station.

Table 26. (Continued)

	Gradient (percent)					
	14	15	16	17	18	19
Fish per sample	1.6(1.7)	0.3(1.5)		0.7(1.7)	3.0(3.2)	
Chinook salmon						
Rainbow trout	0.8(0.5)				3.0(3.2)	
Cutthroat trout	0.4(0.6)					
Dolly Varden		0.3(1.5)		0.2(0.7)		
Brook trout	0.3(0.6)			0.5(0.9)		
Sculpin						
Mtn. whitefish						
Dace						
Other						
Sample Number	9	4	2	6	2	1

Table 26. (Continued)

	Gradient (percent)							
	20	21	24	25	27	28	35	38
Fish per sample	0.2(0.8)	0.5(1.5)	3.0(2.6)					
Chinook salmon								
Rainbow trout	0.2(0.8)	0.5(1.5)	3.0(2.6)					
Cutthroat trout								
Dolly Varden								
Brook trout								
Sculpin								
Mtn. whitefish								
Dace								
Other								
Sample Number	5	2	1	2	1	1	1	1

Table 27. Average per station of fish numbers and length (within parenthesis) by species to stream width.

	Width (feet)						
	3-5.9	6-8.9	9-11.9	12-14.9	15-17.9	13-20.9	21-23.9
Total fish	0.5(0.8)	1.5(0.9)	1.5(1.7)	2.3 (2.8)	2.2(3.2)	2.9(3.0)	6.3(3.0)
Chinook salmon		1.1(0.1)		0.8 (0.2)	0.2(0.2)		2.1(0.3)
Rainbow trout		0.2(0.2)	0.3(0.3)	0.5 (1.0)	1.3(2.0)	2.0(1.3)	3.1(1.8)
Cutthroat trout		0.2(0.5)	0.2(0.2)	0.1 (0.6)	0.3(0.4)	0.1(0.2)	0.3(0.5)
Dolly Varden	0.5(0.8)	0.1(0.1)	1.0(1.4)	0.7 (1.4)	0.2(0.8)	0.4(1.1)	0.3(1.1)
Brook trout				0.04(0.2)	0.1(0.4)	0.3(0.5)	0.2(0.6)
Sculpin				0.1 (0.1)	0.1(0.1)	0.2(0.2)	0.1(0.4)
Mtn. whitefish							
Dace							
Other							0.1(0.2)
Sample Number	4	17	24	55	44	30	27

Table 27. (Continued)

	Width (feet)						
	24-26.9	27-29.9	30-32.9	33-35.9	36-38.9	39-40.9	41-+
Total fish	6.8 (2.8)	5.7 (3.7)	7.7 (4.1)	15.6(3.2)	10.0(4.7)	4.0(4.9)	13.3(3.8)
Chinook salmon	2.0 (0.2)	1.7 (0.2)	3.6 (0.7)	8.6(2.1)	1.0(1.5)		5.7(1.6)
Rainbow trout	4.3 (2.7)	2.1 (2.5)	2.5 (2.0)	5.4(2.7)	8.5(4.8)	4.0(4.9)	7.3(4.7)
Cutthroat trout	0.03(0.2)						
Dolly Varden	0.1 (0.3)	0.5 (1.5)	0.8 (1.2)				
Brook trout	0.1 (0.6)	0.8 (0.2)	0.4 (1.1)	0.5(0.3)			
Sculpin	0.2 (0.2)	0.1 (0.2)	0.2 (0.3)	0.3(0.6)	0.5(2.2)		0.3(1.0)
Mtn. whitefish		0.3 (0.1)	0.1 (0.6)	0.3(2.3)			
Dace		0.04(0.1)		0.1(0.3)			
Other	0.1 (0.2)		0.05(0.1)	0.4(1.2)			
Sample Number	30	23	21	10	2	1	3

Table 28. Average per station of fish numbers and length (within parenthesis) by species to stream depth.

	Depth (inches)							
	3.0-5.9	6.0-8.9	9.0-11.9	12.0-14.9	15.0-17.9	18.0-20.9	21.0-23.9	24.0-26.9
Total fish	0.2(0.2)*	2.7 (2.4)	4.9 (3.5)	5.4 (2.8)	4.7 (3.3)	6.6(3.6)	10.7(4.7)	
Chinook salmon		0.7 (0.2)	1.4 (0.2)	2.6 (0.4)	0.9 (0.4)	1.6(0.9)	0.7(1.0)	
Rainbow trout		1.1 (0.9)	2.6 (2.2)	1.3 (1.4)	2.5 (2.1)	4.7(3.4)	9.7(4.7)	
Cutthroat trout		0.1 (0.3)	0.2 (0.5)	0.2 (0.3)	0.1 (0.1)			
Dolly Varden	0.2(0.2)	0.6 (1.3)	0.4 (1.1)	0.5 (0.8)	0.5 (0.9)	0.1(0.4)		
Brook trout		0.04(0.2)	0.04(0.2)	0.4 (0.6)	0.6 (1.0)			
Sculpin		0.1 (0.1)	0.2 (0.3)	0.2 (0.3)	0.03(0.1)		0.3(1.5)	
Mtn. whitefish			0.02(0.1)	0.2 (0.4)				
Dace				0.01(0.03)	0.03(0.1)			
Other			0.02(0.1)	0.03(0.03)	0.1 (0.3)	0.3(0.4)		
Sample Number	13	76	82	71	33	12	3	1

*Length in inches

Table 29. Average per station of fish numbers and length (within parenthesis) by species to geologic process group.

	Strongly Glaciated	Cryoplanated	Fluvial	Depositional
Total fish	0.2(0.6)		4.6(3.4)	4.5 (2.8)
Chinook salmon			0.6(0.2)	2.0 (0.4)
Rainbow trout	0.2(0.6)		3.3(2.4)	1.2 (1.3)
Cutthroat trout			0.1(0.4)	0.1 (0.2)
Dolly Varden			0.3(0.9)	0.5 (1.1)
Brook trout			0.1(0.3)	0.3 (0.4)
Sculpin			0.1(0.2)	0.2 (0.2)
Mtn. Whitefish				0.1 (0.2)
Dace				0.01(0.03)
Other			0.1(0.1)	0.02(0.1)
Sample Number	6	0	108	168

Table 30. Average per station of fish numbers and length (within parenthesis) by species to geomorphic type.

	Alluvial	Terrace	Glacial Outwash	Valley Train	Alluvial Fan
Total fish	10.2(2.8)	10.0(3.2)	0.8(5.1)	2.5(2.7)	6.3(2.9)
Chinook salmon	7.1(0.8)	0.4(2.8)		0.1(0.1)	5.3(1.1)
Rainbow trout	0.8(1.2)	6.0(3.5)	0.2(1.6)	1.4(1.1)	0.5(1.7)
Cutthroat trout				0.2(0.4)	
Dolly Varden	0.6(1.2)			0.7(1.3)	0.3(0.9)
Brook trout	0.8(0.6)		0.6(3.5)	0.1(0.2)	
Sculpin	0.4(0.5)				0.3(0.3)
Mtn. Whitefish	0.4(1.1)				
Dace	0.1(0.1)				
Other	0.1(0.1)				
Sample Number	35	1	5	102	12

Table 30. (Continued)

	Moraine	Cryoplanated	Cirque	Glacial Trough	Dissected Mountain Slope
Total fish	4.5(2.2)			0.7(2.3)	4.6(3.4)
Chinook salmon	1.3(0.7)				0.6(0.2)
Rainbow trout	2.2(2.0)			0.7(2.3)	3.3(2.4)
Cutthroat trout					0.1(0.4)
Dolly Varden	0.1(0.3)				0.3(0.9)
Brook trout	0.3(1.4)				0.1(0.3)
Sculpin	0.5(0.5)				0.1(0.2)
Mtn. Whitefish					
Dace					
Other					0.1(0.1)
Sample Number	13	4	8	3	108

Table 31. An average per station of fish numbers and length (within parenthesis) by species to elevation of stream channel.

	Elevation (feet)				
	3600-3999	4000-4399	4400-4799	4800-5199	5200-5599
Total fish	13.5(2.6)	11.5(3.1)	5.5(4.8)	10.8(3.6)	3.3 (3.2)
Chinook salmon	2.0(0.6)	2.7(0.9)	0.4(0.5)	6.7(0.7)	1.1 (0.3)
Rainbow trout	10.7(2.7)	8.1(2.7)	4.9(4.4)	2.6(3.1)	1.0 (1.8)
Cutthroat trout		0.5(0.3)		0.1(0.2)	0.3 (0.5)
Dolly Varden		0.1(0.4)	0.1(0.5)	0.3(0.6)	0.3 (0.9)
Brook trout		0.2(0.8)		0.5(0.6)	0.4 (0.8)
Sculpin	0.3(0.8)	0.2(0.5)	0.1(0.3)	0.3(0.3)	0.2 (0.3)
Mtn. whitefish				0.3(0.5)	0.01(0.1)
Dace				0.1(0.1)	
Other	0.5(0.9)	0.1(0.4)	0.1(0.1)		0.03(0.03)
Sample Number	10	22	17	35	80

Table 31. (Continued)

	Elevation (feet)				
	5600-5999	6000-6399	6400-6799	6800-7199	7200-7599
Total fish	1.3 (3.1)	0.9(1.8)	1.4(1.9)		0.6(1.8)
Chinook salmon					
Rainbow trout	0.2 (0.7)	0.1(0.3)	1.2(1.2)		
Cutthroat trout	0.1 (0.4)				0.6(1.8)
Dolly Varden	0.9 (1.9)	0.7(1.3)	0.2(0.6)		
Brook trout		0.1(0.1)			
Sculpin					
Mtn. whitefish	0.02(0.2)				
Dace					
Other					
Sample Number	71	37	9	13	5

Table 32. Average per station of fish numbers and length (within parenthesis) by species to stream order.

	Stream Order				
	1	2	3	4	5
Total fish	5.0(5.0)	0.8(1.7)	1.8(2.7)	6.3 (3.9)	20.1 (2.8)
Chinook salmon			0.3(0.1)	2.3 (0.5)	8.2 (0.9)
Rainbow trout		0.5(0.3)	0.7(1.1)	2.7 (2.9)	10.9 (2.6)
Cutthroat trout		0.1(0.2)	0.2(0.4)	0.1 (0.2)	0.05(0.3)
Dolly Varden	5.0(5.0)	0.5(1.2)	0.5(1.2)	0.3 (0.8)	
Brook trout		0.2(0.2)	0.1(0.3)	0.5 (0.7)	
Sculpin			0.1(0.1)	0.2 (0.3)	0.5 (0.8)
Mtn. whitefish				0.1 (0.2)	0.1 (1.1)
Dace				0.02(0.1)	
Other				0.03(0.3)	0.3 (0.6)
Sample Size	1	43	134	87	21

APPENDIX E:

Tables summarizing hydrochemical information.

Table 33. The streams selected for profile of water quality (1970) with the geologic process group they lie within, and the dominant and subdominant geomorphic type(s) influencing them.

Stream	Geologic Process Group	Dominant Geomorphic Type	Subdominant Geomorphic Types
Cly	Strongly glaciated	Cirque Basin (110)	Glacial trough (111)
Duck Lake (West Fork)	Strongly glaciated	Cirque basin (110)	Cirque basin (110) Glacial trough (111) Glacial scoured (115) Glacial plastered mountain slope (108)
Four Mile (South Fork)	Fluvial	Moderately dissected mountain slope (120b)	Strongly dissected mountain slope (120c)
Four Mile (Upper)	Depositional	Valley train (104)	Rocky ridge (113) Glacial trough (111) Moderately dissected mountain slope (120b)
Indian	Fluvial	Strongly dissected mountain slope (120c)	Alluvial fan (105)
Lick	Depositional	Valley train (104)	Glacial trough (111) Cirque basin (110) Rocky ridge (113) Subalpine rim (114)

Table 33. (Continued)

Stream	Geologic Process Group	Dominant Geomorphic Type	Subdominant Geomorphic Types
Nasty	Fluvial	Moderately dissected mountain slope (120b)	Terrace (102) Cryoplanated (109)
Tailholt	Fluvial	Strongly dissected mountain slope (120c)	Moderately dissected mountain slope (120b)

Table 34. Average chemical analysis of water samples collected from July through September 1970, in tributaries of the South Fork Salmon River by date of collection (p^H in units, remainder in parts per million).

Date	p^H	Total Solids	Total Dissolved Solids	Alkalinity	Hardness	Ca	Mg	Fe	Mn	Na
7/ 6/70	7.34	59.50	40.50	26.50	21.50	4.50	2.63	.422	< .010	1.50
7/17/70	7.76	79.00	60.75	26.50	46.50	4.75	8.38	.041	.028	1.88
8/ 5/70	7.81	74.50	58.00	29.00	21.50	4.88	2.38	< .019	< .010	2.75
8/20/70	8.07	76.00	59.57	21.71	46.29	4.29	8.57	< .090	< .010	1.29
9/ 5/70	7.83	105.50	82.75	36.50	74.00	5.63	12.00	< .048	< .010	1.50
Average	7.76	79.90	60.31	28.04	41.96	4.81	6.79	< .124	< .013	1.78

Table 34. (Continued)

Date	Cl	SO_4	NO_3	PO_4	SiO_2	F	N	Zn	Cu
7/ 6/70	5.00	4.00	.338	.653	10.13	< .010	.078	.091	.055
7/17/70	4.50	1.25	.303	.405	11.70	.031	.150	.007	< .001
8/ 5/70	3.00	< 3.25	.650	.089	12.63	< .034	.475	<.001	< .002
8/20/70	5.57	< 1.00	.200	.770	11.86	< .010	.100	.019	< .026
9/ 5/70	3.25	1.00	.475	.066	13.80	.133	.110	.007	< .003
Average	4.26	1.50	.393	.397	12.02	.044	.182	.025	< .017

Table 34. (Continued)

Date	As	Ba	Cd	Cr	Pb	Ag	K	Total Average
7/ 6/70	< .010	< .020	.003	.031	< .01	< .013	.312	182.2
7/17/70	< .010	< .020	<.001	.021	< .01	< .010	.263	254.3
8/ 5/70	-	-	-	-	< .01	-	.500	226.5
8/20/70	< .010	< .020	<.001	.020	< .01	< .010	.260	245.8
9/ 5/70	< .010	< .020	<.001	.015	< .01	< .010	.238	344.9
Average	< .008	< .016	.001	.017	< .01	< .009	.313	250.7

Table 35. Average chemical analysis by stream of water samples collected from July through September 1970, in tributaries of the South Fork Salmon River (p^H in units; remainder in parts per million).

Stream	p^H	Total Solids	Total Dissolved Solids	Alkalinity	Hardness	Ca	Fe	Mn	Mg
Lick	7.38	80.0	62.8	28.0	45.6	4.0	.576	< .010	8.6
Cly	7.38	67.2	54.4	23.2	38.4	3.6	.162	< .010	3.6
Duck Lake	7.26	56.8	41.4	18.4	26.4	2.0	.038	.010	5.8
Tailholt	8.38	104.8	80.2	49.6	56.0	11.2	< .022	< .010	6.6
Indian	8.16	90.4	67.2	36.0	42.4	6.4	.024	< .038	6.2
Nasty	8.03	83.0	61.5	24.0	41.0	3.5	.030	< .010	7.5
Four Mile (South)	7.60	84.0	62.8	24.0	46.4	3.4	.096	< .050	9.0
Four Mile (Main)	7.90	74.4	52.6	21.6	38.4	4.2	.030	< .010	6.8
Average	7.76	80.1	60.4	28.1	41.8	4.8	.122	< .019	6.8

Table 35. (Continued)

Stream	Na	Cl	SO_4	NO_3	PO_4	SiO_2	F	N	Zn	Cu
Lick	1.20	4.0	1.4	.260	.398	8.76	< .034	.200	.089	< .066
Cly	1.60	3.8	< 1.0	.300	.254	3.00	< .010	.160	.029	< .022
Duck Lake	1.00	5.4	1.6	.280	.158	2.76	< .012	.220	< .005	< .001
Tailholt	2.40	3.0	1.2	.220	.426	17.10	< .068	.180	.005	< .001
Indian	2.60	4.0	< 1.4	.520	.660	20.62	.126	.166	< .002	< .001
Nasty	2.25	4.5	2.0	.825	.340	17.63	< .060	.240	< .001	.002
Four Mile (South)	1.80	4.4	1.4	.520	.370	15.54	< .018	.196	.003	< .001
Four Mile (Main)	1.60	4.8	< 1.6	.360	.478	11.84	< .012	.160	.034	.041
Average	1.80	4.2	1.4	.410	.385	12.16	< .042	.190	.021	.017

Table 35. (Continued)

Stream	As	Ba	Cd	Cr	Pb	Ag	K	Total Average
Lick	< .010	< .020	< .001	.020	< .010	< .015	.160	253.6
Cly	< .010	< .020	< .001	.018	< .010	< .010	.260	208.5
Duck Lake	< .010	< .020	< .001	.013	< .010	< .010	.160	169.8
Tailholt	< .010	< .020	< .001	.030	< .010	< .010	.400	341.9
Indian	< .010	< .020	< .003	.020	< .010	< .010	.480	287.5
Nasty	< .010	< .020	< .002	.043	< .010	< .010	.525	257.0
Four Mile (South)	< .010	< .020	< .001	.015	< .010	< .010	.260	261.9
Four Mile (Main)	< .010	< .020	< .001	.020	< .010	< .010	.320	227.5
Average	.010	< .020	.001	.022	< .010	< .010	.320	250.9

Table 36. Total number and length (in parenthesis) of collected fish by species in streams selected for hydrochemical profile.

	Streams							
	Cly	Duck Lake	Lick	Four Mile (Main)	Nasty*	Four Mile (South)	Tailholt	Indian*
Rainbow trout	2(3.4)		96(4.4)				3(2.6)	
Cutthroat trout		3(8.9)		7(5.0)		3(3.2)		
Dolly Varden						3(5.7)		
Brook trout			4(6.2)					
Chinook salmon			18(2.5)					
Sample size	4	6	13	9	0	5	4	0
Total fish	2	3	118	7		6	3	
Average length	(3.4)	(8.9)	(3.6)	(5.0)		(4.6)	(2.6)	
Total Chemical Units	208	169	253	227	257	261	341	287

*Not sampled.

APPENDIX F:

Tables summarizing undisturbed and disturbed watershed relationships.

Table 37. Disturbed and undisturbed status and type of disturbance for streams in the South Fork Salmon River study area.

Stream	Dominant Geologic Process Group	Areas Disturbed	Completely Undisturbed	Disturbance Type
Bear	Depositional	yes		Logging
Blackmore	Depositional		yes	Livestock
Blue Lake	Fluvial		yes	
Buckhorn	Depositional	yes		Logging, roads
Buckhorn Little	Fluvial		yes	
Burnside	Strongly glaciated		yes	
Cabin	Strongly glaciated	yes		Roads, Logging
Camp	Fluvial	yes		Logging
Circle End	Fluvial		yes	
Cly	Strongly glaciated		yes	
Cougar	Depositional		yes	
Curtis	Depositional	yes		Logging, roads
Dollar	Fluvial	yes		Logging, livestock
Duck	Depositional	yes		Logging, livestock
Fitsum	Depositional	yes		Logging
Four Mile	Depositional		yes	
Goat	Fluvial		yes	
Hum	Depositional		yes	
Indian	Fluvial		yes	
Lick*	Depositional		yes	
Lodgepole	Depositional	yes		Logging, livestock

*Has a road through the drainage but because of location and geomorphic type, it has no influence on the stream.

Table 37. (Continued)

Stream	Dominant Geologic Process Group	Areas Disturbed	Completely Undisturbed	Disturbance Type
Nasty	Fluvial		yes	
Nick	Strongly glaciated		yes	
Rice	Depositional	yes		Logging, livestock
Roaring	Strongly glaciated		yes	
Six-Bit	Fluvial	yes		Logging, roads
South Fork Salmon	Depositional	yes		Roads, logging
Tailholt	Fluvial		yes	
Trail	Fluvial	yes		Roads, logging
Tyndall	Fluvial	yes		Livestock

Table 38. Comparison of variables of stream condition in disturbed versus undisturbed watersheds.

Variable	Disturbed* Mean	Undisturbed** Mean
Gradient (percent)	4.3	7.3
Width (feet)	17	13
Depth (inches)	9	8
Riffle (percent)	59	54
Pool (percent)	41	46
Pool rating (units)	3.9	3.6
Channel materials (percent)		
Boulder	30	35
Rubble	29	25
Gravel	25	19
Fines	16	21
Streambanks (units)		
Cover	1.5	1.8
Condition	1.8	1.6
Type	1.9	1.9
Channel Elevation (feet)	5272	5679
Sample size	262	2207

*Average of stream transects data collected in disturbed watersheds.
**Average of stream transect data collected in undisturbed watersheds.

Table 39. Average per station of fish numbers and length (within parenthesis) by species to disturbed and undisturbed watersheds.

	Land Class	
	Undisturbed	Disturbed
Total fish	3.7 (2.7)	7.7(3.6)
Chinook salmon	0.9 (0.2)	3.8(0.8)
Rainbow trout	1.8 (1.5)	2.7(2.4)
Cutthroat trout	0.2 (0.4)	
Dolly Varden	0.4 (0.9)	0.6(1.4)
Brook trout	0.2 (0.4)	0.1(0.4)
Sculpin	0.1 (0.2)	0.3(0.4)
Mountain whitefish	0.04(0.1)	0.1(0.5)
Dace	0.01(0.02)	
Other	0.02(0.1)	0.1(0.2)
Sample Number	243	48

APPENDIX G:

Tables summarizing variables of the stream and the streamside environment by geomorphic process group and geomorphic type.

Table 40. Average variables of the stream by geologic process group with the plus and minus range (confidence interval) at the 95 percent confidence level in parenthesis.

	Geologic Process Group			
Variable	Strongly Glaciated	Cryoplanated	Fluvial	Depositional
Gradient (percent)	10.6 (0.7)	6.6 (2.4)	6.3 (0.2)	6.6 (0.3)
Width (feet)	9 (1.0)	9 (2.4)	15 (0.5)	14 (0.4)
Depth (inches)	6 (0.7)	8 (2.2)	8 (0.2)	8 (0.1)
Riffle (percent)	44 (4.9)	44 (11.9)	60 (0.6)	50 (0.4)
Pool (percent)	56 (6.3)	56 (15.1)	40 (0.4)	50 (0.3)
Pool Rating (units)	4.1	3.4	3.9	3.7
Channel Composition (percent)				
Boulder	42 (4.8)	14 (3.8)	35 (2.1)	32 (1.8)
Rubble	16 (1.8)	26 (7.0)	30 (1.5)	25 (1.4)
Gravel	31 (3.5)	20 (5.4)	15 (1.3)	21 (1.4)
Fine Sediment	11 (1.2)	40 (10.8)	20 (1.4)	22 (1.5)
Bank Environment (units)				
Cover	1.7 (0.2)	2.0 (0.5)	1.8 (0.02)	1.7 (0.1)
Condition	1.8 (0.2)	1.6 (0.4)	1.6 (0.04)	1.7 (0.1)
Type	1.8 (0.2)	2.0 (0.5)	1.9 (0.02)	1.9 (0.02)
Channel Elevation (feet)	6569	6151	4971	5626
Sample Size	300	55	858	1218

Table 41. Streams selected to represent certain dominant (D) and subdominant (S) geomorphic types in the South Fork Salmon River drainage.

LANDTYPE \ Stream	Bear	Bear (South)	Blackmare (Main)	Blue Lake (Lower)	Blue Lake (Middle)	Blue Lake (Upper)	Buckhorn (Little)	Buckhorn (Lower)	Buckhorn (Main)	Buckhorn (North)	Buckhorn (South)	Buckhorn (Upper)	Buckhorn (West)	Burnside	Cabin (101)	Cabin (104)	Cabin (103)	Camp (111)	Camp (106)	Circle End	Cly	Cly III	Cougar	Curtis (Main)	Curtis (East)	Curtis (Middle)	Dollar (Lower)	Dollar (Upper)	Duck (Lower)	Duck (Upper)	Fitsum	Fitsum (North)	Four Mile (Main)	Four Mile (South)	Goat	Hum	Indian
Alluvial (101)															D			S_2						D													
Terrace (102)																																					
Glacial outwash (103)															S_1		D																				
Valley train (104)		D			D				D	D	D	D	D			D	S_1				S_2		D		D				D	D	S_1		D		D	D	
Alluvial fan (105)																																					S_1
Moraine (106)															S_2			S_1	D											S_2							
Toe slope (107)																																					
Glacial plastered (108)					S_1											S_1	S_3	S_3																			
Weakly glaciated (109)																											S_1	D									S_2
Cirque basin (110)			D	D		D															D																
Glacial trough (111)																S_2	S_2	D			S_1	D								S	D_1						
River spur (112)																																					
Rocky ridge (113)																																					
Subalpine rim (114)																																					
Glacial Scoured (115)																																					
Faulted glacial Scoured (116)														D																							
Dissected mountain (120)					D		D	D		S_1										D						D	D				D	D		D			D
Structural basin (121)																																					
River breaks (122)																																					
Faulted bench (123)																																S_1					

Table 41. (Continued)

LANDTYPE / Stream	Lick	Lodgepole (Lower)	Lodgepole (Upper)	Nasty	Nick	Rice	Roaring	Salmon River (South)	Six Bit (Lower)	Six Bit (Upper)	Tailholt	Trail	Tyndall
Alluvial (101)						S_1		D					
Terrace (102)													
Glacial outwash (103)									S_1				
Valley train (104)	D	D	D			D	D			D			
Alluvial fan (105)													S
Moraine (106)	S_1												
Toe lope (107)													
Glacial plastered (108)								S_2		S_2			
Weakly glaciated (109)								S_1					
Cirque basin (110)						S_2							
Glacial trough (111)	S_2				D								
River spur (112)								S_3					
Rocky ridge (113)													
Subalpine rim (114)													
Glacial scoured (115)													
Faulted glacial scoured (116)													
Dissected mountain (120)				D					D	S_1	D	D	D
Structural basin (121)													
River breaks (122)													
Faulted bench (123)													

Table 42. Average of variables of the condition of study streams by geomorphic type with plus and minus range (confidence interval) at the 95 percent confidence level in parenthesis.

Variable	Geomorphic Type Code				
	101	104	105	106	109
Gradient (percent)	3.6 (0.2)	8.3 (0.5)	2.3 (0.3)	4.9 (0.5)	6.5 (2.4)
Width (feet)	17 (1.0)	13 (0.5)	13 (1.1)	12 (1.7)	9 (1.8)
Depth (inches)	8 (0.5)	8 (0.3)	7 (0.7)	6 (0.7)	8 (1.4)
Riffle width (percent)	53 (1.1)	54 (0.4)	54 (1.4)	58 (1.1)	44 (1.3)
Pool width (percent)	47 (1.0)	46 (0.4)	46 (1.0)	42 (1.2)	56 (1.6)
Pool rating (units)	3.7	3.7	3.8	4.1	3.3
Channel Materials (percent)					
Boulder	15 (2.8)	41 (2.4)	16 (5.7)	22 (9.1)	12 (6.9)
Rubble	27 (3.2)	23 (1.7)	23 (5.8)	32 (5.3)	26 (8.9)
Gravel	32 (3.9)	16 (1.5)	21 (5.1)	33 (5.8)	20 (8.2)
Fine sediment	26 (3.4)	20 (1.9)	40 (7.4)	13 (3.8)	42 (10.8)
Streambanks (units)					
Cover	1.8 (0.04)	1.7 (0.02)	1.9(0.1)	1.6 (0.1)	2.0 (0.03)
Condition	1.6 (0.06)	1.6 (0.03)	1.4(0.1)	1.9 (0.4)	1.6 (0.1)
Type	1.8 (0.05)	1.8 (0.03)	2.0(0.05)	1.9 (0.04)	1.9 (0.05)
Channel Elevation (feet)	5614	5675	5422	5530	6170
Sample Size	243	792	67	124	55

Table 42. (Continued)

Variable	Geomorphic Type Code 110	111	120	102	103
Gradient (percent)	8.8 (0.9)	13.4 (1.1)	6.4 (0.3)	3.0 (0.0)	2.7 (0.5)
Width (feet)	7 (0.5)	10 (1.1)	15 (1.8)	26 (9.3)	13 (1.3)
Depth (inches)	5 (0.4)	7 (0.9)	8 (0.3)	16 (2.6)	12 (1.3)
Riffle width (percent)	43 (0.4)	40 (0.9)	60 (0.5)	65 (7.3)	38 (1.9)
Pool width (percent)	57 (0.5)	60 (1.0)	40 (0.4)	35 (2.6)	62 (1.8)
Pool rating (units)	4.3	4.0	4.0	4.0	2.9
Channel Materials (percent)					
Boulder	40 (5.4)	50 (7.1)	36 (2.1)	78 (14.3)	8 (7.1)
Rubble	12 (3.0)	22 (5.0)	30 (1.9)	17 (14.0)	32 (9.1)
Gravel	35 (4.9)	24 (5.6)	15 (1.3)	2 (5.8)	14 (5.9)
Fine sediment	13 (3.5)	4 (2.4)	19 (1.7)	3 (6.6)	46 (10.7)
Streambanks (units)					
Cover	1.8 (0.05)	1.8 (0.04)	1.8 (0.02)	1.5 (0.0)	2.0 (0.0)
Condition	1.9 (0.03)	1.9 (0.1)	1.6 (0.02)	1.5 (0.0)	1.4 (0.1)
Type	1.8 (0.1)	2.0 (0.04)	1.9 (0.02)	1.8 (0.4)	2.0 (0.04)
Channel Elevation (feet)	6941	5987	4977	4310	5370
Sample Size	164	104	821	5	30

Table 42. (Continued)

Variable	Landtype Code 116	121
Gradient (percent)	10.1 (2.8)	5.2 (0.3)
Width (feet)	10 (2.7)	11 (1.2)
Depth (inches)	10 (2.1)	8 (0.7)
Riffle width (percent)	50 (2.2)	45 (1.6)
Pool width (percent)	50 (1.5)	55 (1.9)
Pool rating (units)	3.4	3.6
Channel Materials (percent)		
Boulder	30 (13.3)	31 (10.0)
Rubble	13 (7.2)	17 (6.1)
Gravel	32 (11.7)	9 (3.5)
Fine sediment	25 (9.9)	43 (9.6)
Streambanks (units)		
Cover	1.5 (0.1)	1.7 (0.1)
Condition	1.5 (0.1)	1.2 (0.1)
Type	1.4 (0.1)	2.0 (0.0)
Channel Elevation (feet)	-	4788
Sample Size	30	30

Table 43. Geomorphic types containing or not containing perennial streams based on the sampling program.

Geologic Process Group	Geomorphic Type	Map Code	Contains Streams	
Strongly Glaciated				
	Cirque basin	110	yes	
	Faulted glacial scoured uplands*	116	**	
	Glacial plastered mountain slope	108		no
	Glacial scoured mountain slope*	115		no
	Glacial trough	111	yes	
	Rocky ridge	113		no
	Subalpine rim	114		no
	Toe slope	107		no
Cryoplanated				
	Uplands	109	**	
Fluvial	Dissected slope	120	yes	
	Faulted bench	123		no
	Oversteepened canyon	122		no
	River spur	112		no
	Structural basin	121	**	
Depositional				
	Alluvial	101	yes	
	Alluvial fan	105	yes	
	Glacial outwash	103	yes	
	Moraine	106	yes	
	Terrace	102	**	
	Valley train	104	yes	
		Percent	55	45

*These two geomorphic types are so similar that often they are considered the same.
**Occasionally

APPENDIX H:

Table summarizing the explained observed variation (multivariate analysis) considering stream descriptive variables with fish numbers.

Table 44. Explained observed variation (multivariate analysis) considering stream descriptive variables with fish numbers.

Stream Variable	Total Fish and Species									
	Total Fish		Salmon		Rainbow		Cutthroat		Dolly Varden	
	R^2	R	R^2	R	R^2	R	R^2	R	R^2	R
Elevation	.09	.30	.01	.12	.15	.39	.00	.06	.00	.05
Width	.12	.35	.03	.18	.17	.41	.01	.12	.00	.05
Pool Rating	.18	.42	.10	.32	.18	.43	.03	.18	.04	.19
Bank Cover (L)	.21	.46	.11	.34	.20	.45	.04	.19	.10	.31
Rubble	.23	.48	.13	.36	.22	.47	.04	.19	.10	.31
Gradient	.24	.49	.13	.36	.23	.48	.04	.19	.10	.32
Pool	.25	.50	.14	.37	.23	.48	.04	.20	.11	.34
Riffle	.26	.51	.15	.39	.23	.48	.04	.20	.11	.34
Bank Cover (R)	.27	.52	.15	.39	.28	.53	.04	.20	.12	.34
Depth	.27	.52	.16	.40	.28	.53	.05	.21	.12	.35
Bank type	.28	.53	.18	.42	.29	.54	.05	.22	.13	.37
Boulder	.28	.53	.19	.43	.30	.55	.06	.24	.14	.38
Gravel	.28	.53	.19	.43	.30	.55	.06	.24	.14	.38
Fine Sediment	.28	.53	.19	.43	.30	.55	.06	.24	.14	.38
Pool Rating	.30	.54	.20	.45	.32	.56	.06	.25	.16	.39
Pool Feature	.31	.56	.21	.46	.33	.58	.07	.26	.17	.42
Watershed Condition	.31	.56	.21	.46	.34	.58	.07	.27	.17	.42
Bank Condition (L)	.31	.56	.21	.46	.34	.58	.09	.31	.18	.43
Bank Condition (R)	.32	.56	.23	.48	.35	.59	.10	.32	.18	.43
Pool Feature	.32	.57	.23	.48	.35	.59	.10	.32	.21	.45